This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Digitized by Google

HARVARD UNIVERSITY

LIBRARY OF THE
MINERALOGICAL
LABORATORY

UNIVERSITY MUSEUM

Digitized by Google

HARVARD UNIVERSITY,
CAMBRIDGE,
MASS.
Dept. of Mineralogy & Petrography.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 87

WASHINGTON
GOVERNMENT PRINTING OFFICE
1897

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

A SYNOPSIS

OF

AMERICAN FOSSIL BRACHIOPODA

INCLUDING

BIBLIOGRAPHY AND SYNONYMY

BY

CHARLES SCHUCHERT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1897

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Letter of transmittal	9
Preface	11
Chapter I. Geologic development and geographic distribution of American fossil Brachiopoda	13
Geologic development	13
Geographic distribution	17
Table I Brachiopod genera alphabetically arranged, their geologic distribution, and North American specific representation	18
Table II. North American Paleozoic representation of the orders, superfamilies, and families, geologically arranged	25
Tables of North and South American species, geologically arranged	26
Table III. Cambrian Brachiopoda	26
Table IV. Ordovician Brachiopoda	29
Table V. Silurian Brachiopoda	36
Table VI. Devonian Brachiopoda	43
Table VII. Carboniferous and Permian Brachiopoda	57
Table VIII. Mesozoic Brachiopoda	67
Table IX. Cenozoic and recent Brachiopoda	68
Table X. South American fossil Brachiopoda	69
Chapter II. Brachiopod terminology, applied to fossil forms	73
Chapter III. Biologic development of the Brachiopoda	78
Ordinal development	78
Atremata	78
Neotremata	79
Protremata	81
Telotremata	85
General development	88
Structural characters	90
The protegulum	90
The prodeltidium	91
Significance of the prodeltidium	93
Development of cardinal areas and articulation	97
Development and significance of the deltidium	98
The chilidium	99
Origin and function of the spondylium	99
Crura and cruralium	102
Morphologic equivalents	102
Summary	102
Chapter IV. Morphology of the brachia, by Charles E. Beecher	105
Classification of brachial structures	106
Leiolophus stage	107
Taxolophus stage	107
Trocholophus stage	107
Schizolophus stage	108

Digitized by Google

Chapter IV. Morphology of the brachia, by Charles E. Beecher—Continued.
Classification of brachial structures—Continued. Page.
Ptycholophus stage 109
Zugolophus and plectolophus stages 109
Spirolophus stage 110
References 112
Chapter V. Classification of the Brachiopoda 113
Historical 113
Principles of classification 115
Classification and synonymy 118
Atremata 119
Telotremata 121
Neotremata 129
Protremata 131
Diagram illustrating geologic distribution of families 134
Synopsis of the divisions of Brachiopoda higher than genera 136
Chapter VI. Index and bibliography of American fossil Brachiopoda 138

Digitized by Google

ILLUSTRATIONS.

	Page
PLATE I. Diagram illustrating geologic distribution of families	134
FIG. 1. Diagram giving the geologic distribution of the brachiopod orders	96
2. Stages of growth of the lophophore in Thecidea, Cistella, and Megathyris	108
3. Stages of growth of the lophophore in the Terebratellidæ and Terebratulidæ	109
4. Metamorphoses of the brachidium in Dielasma turgida	110
5. Early stages of the lophophore of Glottidia and adult brachia in Lingula and Hemithyris	110
6. Metamorphoses of the brachidium of Zygospira and the brachidium of Rhynchospira	111

Digitized by Google

Digitized by Google

LETTER OF TRANSMITTAL.

UNITED STATES NATIONAL MUSEUM,
Washington, D. C., January 9, 1897.

SIR: I have the honor to transmit herewith the manuscript of A Synopsis of American Fossil Brachiopoda, including Bibliography and Synonymy, which has been prepared out of official hours. It is presented with a view to its publication as a bulletin by the United States Geological Survey.

CHARLES SCHUCHERT.

Hon. CHARLES D. WALCOTT,
Director of the United States Geological Survey.

Digitized by Google

Digitized by Google

PREFACE.

Probably no continent is more productive of well-preserved Paleozoic brachiopods than North America. Throughout the vast territory of the United States which is drained by the Mississippi River the strata have suffered little change, and it is this region which has furnished nearly all the material, from the Middle Ordovician to the top of the Upper Carboniferous. The numerous species of American Cambrian brachiopods which are found scattered along the margins of this great interior plateau and throughout New Brunswick have also aided largely in determining the evolution of the class. To Mr. Walcott, Director of the United States Geological Survey, much honor is due for making clear the structure of brachiopods from this system.

The present synopsis was begun in Cincinnati eleven years ago, while the writer was engaged in paleontologic work with Mr. E. O. Ulrich. In 1887, when the list had increased to about 700 cards, the position of assistant to Prof. James Hall was entered upon. A nearly complete library of American paleontologic literature thus became available to the writer, and during the next two years the greater part of his leisure was devoted to recording brachiopod literature. The large private collection of brachiopods belonging to Professor Hall, together with the many public and private collections then under investigation by Hall and Clarke, also afforded the writer abundant facilities and a rare opportunity for the study of this class. Every occasion was embraced to examine into the synonymy suggested by authors, and in this work it is believed much has been attained. In addition to the above collections and to the material in his own possession, the writer has also studied the specimens belonging to this class in the American Museum of Natural History, Yale University Museum, Cincinnati Society of Natural History, and the United States National Museum. In 1890 the present catalogue comprised upward of 3,500 cards, arranged in boxes having a united length of about 4 feet. It now includes nearly 10,000 references relating to North and South American fossil brachiopods.

It is believed that with the exception of local faunal lists all the literature of North and South America pertaining to this subject is recorded in the following synopsis. Much possible synonymy which the writer could not satisfactorily determine is noted under "Observations." The complete known distribution of widely dispersed species

Digitized by Google

is not always given, only the more important localities being cited. In every case, however, the locality first mentioned is believed to be the original one.

For the proper generic disposition of the species the work of Hall and Clarke[1] has been closely followed, and the entire synopsis is arranged alphabetically to facilitate easy finding. The geologic distribution of the genera is given at the end of Chapter I, and their systematic position in the classification in Chapter V. The evolution of the lophophore, from the simple crescentic condition with few tentacles of the protegulum to the most complex condition in the Terebratulacea, described in Chapter IV, is wholly the work of Dr. Beecher. From the development of this organ in recent species the peculiarly complicated growth of the lophophore in the Spiriferacea is also explained. Some of the embryonic brachial conditions are likewise indicated as probably existing in a mature condition in early Paleozoic genera.

The danger of neglecting young or small specimens of any organism can not be too often impressed upon collectors. Often by means of such fossils intricate problems in phylogeny or life history may be solved. To have much value, however, young specimens must be very small, and these can not be picked up in the field. Where brachiopods abound, whether in clay or of a siliceous nature in limestone, material should be collected in bulk and prepared later by washing or etching with weak muriatic acid. This method of collecting generally results in securing fossils that otherwise will not be observed.

To Dr. Charles E. Beecher, of Yale University Museum, the best thanks of the writer are especially due for the continued interest taken in this catalogue, as well as for valuable suggestions regarding classification; and to Mr. Charles D. Walcott, Director of the United States Geological Survey, for favors relating to the publication of the paper.

To the following gentlemen the grateful acknowledgments of the writer are due for specimens or for suggestions in synonymy: Prof. J. F. Whiteaves, Canadian Geological Survey; Prof. H. S. Williams, Yale University; Director Charles D. Walcott, Dr. W. H. Dall, Dr. T. W. Stanton, and Dr. George H. Girty, United States Geological Survey; Prof. R. P. Whitfield, American Museum of Natural History; Prof. N. H. Winchell, State geologist of Minnesota; Mr. E. O. Ulrich, Newport, Kentucky; Mr. S. A. Miller, Cincinnati, Ohio; Mr. R. R. Rowley, Louisiana, Missouri, and Mr. D. K. Gregor, Fulton, Missouri; and to Dr. C. Davies Sherborn, of the British Museum, for valuable suggestions in bibliography.

C. S.

[1] Palæontology of New York, Vol. VIII, 1892–95.

Digitized by Google

A SYNOPSIS OF AMERICAN FOSSIL BRACHIOPODA, INCLUDING BIBLIOGRAPHY AND SYNONYMY.

By Charles Schuchert.

CHAPTER I.

GEOLOGIC DEVELOPMENT AND GEOGRAPHIC DISTRIBUTION OF AMERICAN FOSSIL BRACHIOPODA.

GEOLOGIC DEVELOPMENT.

Upward of 2,500 species of brachiopods have been described or identified from the sediments of the North and South American continents and adjacent islands. Of these, 2,053 are recognized in this catalogue, the other species, about 20 per cent, being considered as synonyms.

Little is known of the fossil forms from South America. Forty-eight genera are represented by 159 species, ranging from the Cambrian upward. Of these, 125 are from the Paleozoic and 34 from the Mesozoic. The Cambrian, Ordovician, and Jurassic brachiopods require further study, since authors have given little or no attention to their internal characters, and also have too readily identified them with well-known European species.

In North America there are 1,922 species, of which 1,859 are restricted to the Paleozoic. In 1880 Zittel,[1] on the basis of Bigsby's Thesaurus, gave a total of 4,243 species of Paleozoic Brachiopoda. Since Bigsby's compilation the total has probably been increased to 6,000 species, about one-third of which occur in North America. On account of their good preservation and great abundance, both in species and individuals, throughout the Paleozoic, the brachiopods in North America are of particular value in stratigraphic and correlative geology.

In the Mesozoic there is a remarkable scarcity of brachiopods, since but 49 species have been recorded, and many of these are rare. The Cenozoic representation is even smaller, there being but 14 species. This scarcity of post-Paleozoic brachiopods is very apparent in the oldest system of the Mesozoic, the Triassic, from which but 11 species have been described, whereas in the Carboniferous there are 478

[1] Handbuch der Palæontologie, Vol. I, 1880, pp. 709–710.

Digitized by Google

species. In marked contrast, also, is this lack of brachiopod continuity when compared with the Alpine Trias, from which Bittner has described 380 species; but nowhere else is this system known to have so large a development. This evidence not only indicates a decadence of the class during late Paleozoic, but epeirogenic movements as well near the close of the American Carboniferous, for none of the 478 species of this system pass into the Trias.

With the Trias a new facies of brachiopod life is initiated; many of the familiar types of Paleozoic shells had, at that time, long since ceased to live or had ended in the Carboniferous or Permian. The superfamilies Acrotretacea, Obolacea, and Pentameracea have died out, while the Lingulacea, Discinacea, Craniacea, Strophomenacea, and Spiriferacea are sparingly represented, and commonly by small species. Before the close of the Jurassic system the Spiriferacea also disappeared, so that since the Cretaceous era the class is practically represented by rhynchonellas and terebratulas, with a few scattering species of Lingula, Crania, and Discinisca.

In the American Jurassic there are but 13 species, and all are rare. How remarkable is this representation when contrasted with the Jura of Europe, where certain beds of the Lias, Dogger, and Malm terranes contain millions of specimens of a few species belonging to the families Terebratulidæ and Rhynchonellidæ.[1] The Cretaceous has 26 species, also a meager representation, and yet "outside of Europe, North America is the most important for the occurrence of Cretaceous Brachiopoda."[2] The American Eocene has 9 species and the Neocene 5. The disparity between the European and American Cenozoic brachiopod faunas is partly due to the scarcity of marine deposits representing the different horizons in America.

The geographic distribution of the 63 post-Paleozoic species shows that 30 are found along the eastern and southern border of the United States, 15 on the Pacific Coast, and 18 from the Arctic Circle south to about the fortieth parallel and between the one hundredth and the one hundred and twentieth meridians.

The Trias of eastern North America, with its unfavorable shore deposits, has but one species, while the Cordilleran Sea[3] to the east of the Rocky Mountains has 7, and these were there followed by 5 other species in the Jurassic system. A larger brachiopod fauna may have existed in the deeper waters of the Atlantic Trias, but nothing of it is known. In Cretaceous times conditions were again more favorable, 10 forms being recorded from the Atlantic border of North America, 10 from the Pacific, and 6 from the interior Cordilleran Sea. Toward the close of the Cretaceous the Cordilleran Sea became more and more

[1] Zittel, op. cit., p. 714.

[2] Ibid., p. 716.

[3] For the areas covered by this and the Mississippian and Appalachian seas, see Walcott's presidential address, Geologic time as indicated by the sedimentary rocks of North America: Proc. Am. Assoc. Adv. Sci., Vol. XLII, 1893.

Digitized by Google

unfit for marine life, and no brachiopods are known from the Tertiary deposits of this area. From the eastern North American Tertiary 9 species are known, but only 2 from the Pacific border. In recent times conditions are apparently more favorable for the introduction and existence of brachiopods from other areas, as 14 species have been dredged from the Atlantic and 24 from the Pacific continental plateaus of North America.

The living forms are universally distributed in the seas of the world. Their range in depth is no less extended. They occur in shallow waters, at low-water mark, and varying degrees of depth, from 200 to 600 fathoms being the usual limit of the majority of species. Several far-ranging abyssal species were dredged in from 1,000 to 2,000 fathoms. The delicate transparent shell of that interesting little Terebratuloid, Liothyrina Wyvillei Davidson, was actually obtained in a living condition by the *Challenger* expedition from the enormous depth of 2,900 fathoms, or 3¼ miles, at the bottom of the South Atlantic Ocean.[1]

In the North American Cambrian there are 116 species described, a far greater development than in any other country. Davidson records but 14 species in Great Britain, while Bigsby, in 1868, gave the total for this system as 126 for all countries. In the next, or Ordovician, system the rapidity of brachiopod differentiation is remarkable. There are 319 species known in North America, an increase nearly three times that of the Cambrian. Bigsby's percentage of increase for this system is even greater, since in 1868 he listed 556 Ordovician species, which represent a growth of nearly four and one-half times that of his Cambrian total of 126.

While there is much specific differentiation throughout the Ordovician, it is a notable fact that the essential types of brachiopods of this system are also found near its base in the Calciferous. In the Chazy, or next younger horizon, the species are very much like those of the Trenton, where this class has great and varied representation, which is maintained to the end of the Ordovician. It is also true that the species become more generalized structurally as the Cambrian is approached, and most rapidly so toward the base of the Ordovician.

The evolution of the Cambrian brachiopods is similar in its history to that of the Ordovician, except that there the differentiation was along more fundamental structural lines. In the following table it is seen that the four orders of the class Brachiopoda began with the Lower Cambrian, and that throughout this system differentiation was mainly of family importance, since none of these divisions has many genera or species. Where minor groups occur in quantity it is always in the more primitive divisions, as in the Atremata. In none of the other three orders is there a similar rapid differentiation in the Cambrian.

[1] Agnes Crane, Geol. Mag., Dec. IV, Vol. II, 1895, p. 3 (extract).

Digitized by Google

Table showing the differentiation of the Brachiopoda during Cambrian time.

	Number of species.	Number of genera.	Number of families.	Atremata species.	Neotremata species.	Protremata species.	Telotremata species.
Upper Cambrian ...	51	14	8	30	4	17	.....
Middle Cambrian...	39	12	5	19	16	4	.....
Lower Cambrian ...	31	12	7	17	5	8	2

The earliest deep-water deposits of the Silurian, the Clinton formation, have a brachiopod fauna which is quite different from that of the Ordovician. The Atremata, Neotremata, and Protremata are much like those of the Ordovician, but the Spiriferacea of the Telotremata, the most characteristic brachiopods of the Silurian, have here attained a great variety of forms, with varied brachydial structures. Throughout the American Silurian the brachiopods show little structural differentiation, but in the Lower Helderberg, at the base of the Devonian, the spire-bearers are changing and assuming characters which are fully developed in the higher Devonian. Here also occur the oldest loop-bearers, or Terebratulacea, though the ontogeny of Zygospira seems to show that this superfamily originated in the Ordovician.

In the Mississippian Sea deposition was apparently quite continuous throughout Devonian and Carboniferous times, and not much interrupted by earth movements. The faunas of these systems in this area show no rapid evolution along any of the brachiopod phyla. The species of the basal member of the Carboniferous, the Waverly or Kinderhook, are not unlike those of the Chemung of the Upper Devonian, nor is there any great faunal difference between the Kaskaskia of the Lower Carboniferous and the productive Coal Measures above.

From the foregoing rapid summary of the geologic history of American brachiopods, it follows that differentiation in the Paleozoic is most rapid near the base of the older systems, and diminishes in force from the older to the younger geologic divisions. While earth movements in America were greater and more numerous during the early Paleozoic than later in and just previous to the close of this time, yet the early and rapid evolution of the class is probably due not only to the varying conditions produced by these movements but also to the greater plasticity of the class during the Cambrian and Ordovician eras.

There are 311 species in the American Silurian, increasing to 662 in the Devonian, while the Carboniferous representation declines to 478 species. In 1880 Zittel gave a total of 1,366 species for the Devonian, 871 for the Carboniferous, and but 30 for the Permian. Waagen's researches in the Permian of India, however, have increased this representation considerably.

There is no more striking evidence than these figures needed to show

Digitized by Google

the very rapid increase of the class during the Ordovician, its culmination in the Devonian era, and its rapid decline in the Carboniferous.

Of the 230 established Paleozoic genera, not fewer than 186 are represented in North America.

GEOGRAPHIC DISTRIBUTION.

The geographic distribution of North American Paleozoic brachiopods is extensive, since 30 per cent, or 537 species, had great areal or horizontal dispersion. One hundred and seventeen species are found in both the Mississippian and Cordilleran seas, and of these 36 are also known to occur in foreign countries. The number of species common to North America and other continents, however, is 121.

When considered chronologically, it is observed that 20 per cent of the Cambrian brachiopods have great geographic distribution, and that this increases to 32 per cent in the Ordovician, Silurian, and Devonian, and declines to 28 per cent in the Carboniferous. Greatest specific dispersion, however, is most noticeable in the Devonian and Carboniferous, where *Atrypa reticularis*, *Leptæna rhomboidalis*, *Orthothetes crenistriatus*, *Productus semireticulatus*, *P. punctatus*, *Rhynchonella pleurodon*, *Spirifer disjunctus*, and *S. striatus* have almost world-wide distribution and great vertical or chronologic range. Many similar species common to America and several European countries could be mentioned.

Specific distribution increases with ordinal rank. In the radical order Atremata 25 per cent had dispersion, increasing to 27 per cent in the Neotremata, and to 32 per cent in the Protremata and Telotremata.

From the above considerations it is evident that brachiopods, as a rule, can not be of great value in correlating over wide areas minor Devonian, but particularly Carboniferous, horizons. In the Cambrian, Ordovician, and Silurian, however, these fossils are of great value for stratigraphic purposes. Since post-Paleozoic brachiopods are not common in America, they can have little stratigraphic value, but in the Trias and Jura of Europe, where species and individuals are common, reliance can be placed upon them, and they are there regarded as next in importance to the Ammonoidea for correlation. When paleontology shall have advanced sufficiently, so that extracontinental correlation of Paleozoic formations can be taken up in detail, it will be seen that brachiopods, because of their wide dispersion, abundance, and favorable preservation, will be of great service in working out paths of migration and intercommunicating oceanic basins.

Digitized by Google

TABLE I.—*Brachiopod genera alphabetically arranged, their geologic distribution, and North American specific representation.*

[In the column "Ordinal rank" A., N., P., T. equal the first letters of Atremata, Neotremata, Protremata, and Telotremata, respectively. The geologic occurrence of non-American genera or the earlier appearance or later continuance of American genera in other countries is indicated by a black line. Small superior numerals indicate the number of species having distribution.]

Genus.	Ordinal rank.	South American species.	North American species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Permian and Carboniferous.	Triassic.	Jurassic.	Cretaceous.	Tertiary.	Recent.
Acambona White	T.		2					2					
Acanthothyris d'Orbigny	T.									—			
Acrothele Linnarson	N.		5	5^1									
Acrotreta Kutorga	N.		5	5^1									
Actinoconchus McCoy	T.							—					
Agulhasia King	T.										—	—	—
Amboccelia Hall	T.		7				5^2	2					
Amphiclina Bittner	T.								—				
Amphiclinodonta Bittner	T.								—				
Amphigenia Hall	P.	1	4				4^1						
Amphitomella Bittner	T.								—				
Anabia Clarke	T.	1				—							
Anastrophia Hall	P.		4			4^2							
Ancistrocrania Dall	N.										—		
Anisactinella Bittner	T.								—				
Anomactinella Bittner	T.								—				
Anoplia Hall and Clarke	P.		1				1^1						
Anoplotheca Sandberger	T.	1	10			3^2	7^2						
Antiptychina Zittel	T.									—	—		
Athyris McCoy	T.		29			3	9^3	17^5	—				
Atrypa Dalman	T.	1	20			10^5	11^5						
Atrypina Hall and Clarke	T.		4			3^1	1^1						
Aulacorhynchus Dittmar	P.		1					1^1					
Aulacothyris Douvillé	T.								—		—		
Aulosteges Helmersen	P.							—					
Austriella Bittner	T.								—	—			
Barroisella Hall and Clarke	A.		1				1^1						
Beachia Hall and Clarke	T.		1				1^1						
Beecheria Hall and Clarke	T.		1					1					
Billingsella Hall and Clarke	P.		12	9^2	2	?1							
Bilobites Linnæus	P.		3			2^1	1^1						
Bittnerula Hall and Clarke	T.								—				
Botsfordia Matthew	A.		1	1									
Bouchardia Davidson	T.												—
Branconia Caegel	P.						—						
Cadomella M. Chalmas	P.									—			
Camarella Billings	P.		10		9^2	1							
Camarophorella Hall and Clarke	P.		1					1					
Camarophoria King	P.		9				1	8^2					
Camarospira Hall and Clarke	T.		1				1^1						
Camarotœchia Hall and Clarke	T.	1	32		1^1	9^2	20^{10}	4^2					
Camerothyris Bittner	T.								—	—			
Capellinia Hall and Clarke	P.		1			1							
Cardinocrania Waagen	N.							—					

Digitized by Google

TABLE I.—*Brachiopod genera alphabetically arranged, etc.*—Continued.

Genus.	Ordinal rank.	South American species.	North American species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Permian and Carboniferous.	Triassic.	Jurassic.	Cretaceous.	Tertiary.	Recent.
Catazyga Hall and Clarke	T.		3		3^{2}								
Centronella Billings	T.	2	10				7^{2}	3^{1}					
Charionella Billings	T.		1				1^{1}						
Chascothyris Holzapfel	T.												
Chonetella Waagen	P.												
Chonetes Fischer de Waldheim	P.	13	47			5^{2}	22^{10}	22^{12}					
Chonetina Krotow	P.												
Chonopectus Hall and Clarke	P.		1					1^{1}					
Chonostrophia Hall and Clarke	P.	1	4				4^{2}						
Christiania Hall and Clarke	P.		1				1						
Cincta Quenstedt	T.												
Cistella Gray	T.												
Cleiothyris King	T.	1	10					10^{3}					
Clintonella Hall and Clarke	T.		1			1							
Clitambonites Pander	P.	1	3		3^{1}								
Clorinda Barrande	P.		5			5^{2}							
Cœnothyris Douville	T.												
Conchidium Linnæus	P.		20			18^{3}	?2						
Conotreta Walcott	N.		1		1^{1}								
Cranæna Hall and Clarke	T.		2				2^{2}						
Crania Retzius	N.		34	?1	9^{3}	9^{1}	11^{3}	4^{1}					
Craniella Œhlert	N.		3		?1	?1	1^{1}						
Craniscus Dall	N.												
Cruratula Bittner	T.												
Cryptacanthia White and St. John	T.		1					1					
Cryptonella Hall	T.		11			1	9^{3}	3^{1}					
Cryptopora Jefferys	T.												
Cyclorhina Hall and Clarke	T.		1				1^{1}						
Cyclospira Hall and Clarke	T.		2		1^{1}	?1							
Cyrtia Dalman	T.		6			3^{3}	2^{1}	1^{1}					
Cyrtina Davidson	T.	1	21			1^{1}	15^{6}	5					
Dallina Beecher	T.												
Dalmanella Hall and Clarke	P.	1	38		22^{10}	4^{2}	11^{4}						
Davidsonella M. Chalmas	P.												
Davidsonia Bouchard	P.												
Davieslella Waagen	P.												
Dayia Davidson	T.												
Delthyris Dalman	T.		7			2^{1}	5^{4}						
Derbya Waagen	P.	1	12					12^{2}					
Dicamara Hall and Clarke	T.												
Dictyonella Hall	P.		5			5^{1}							
Dictyothyris Douville	T.												
Dielasma King	T.	2	11				1^{1}	10^{6}					
Dielasmina Waagen	T.												
Dignomia Hall	A.		1				1						
Dimerella Zittel	T.												
Dinarella Bittner	T.												
Dinobolus Hall	A.		4		3^{1}	1^{1}							
Dinorthis Hall and Clarke	P.		12		12^{3}								
Dioristella Bittner	T.												

Digitized by Google

TABLE I.—*Brachiopod genera alphabetically arranged, etc.*—Continued.

Genus.	Ordinal rank.	South American species.	North American species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Permian and Carboniferous.	Triassic.	Jurassic.	Cretaceous.	Tertiary.	Recent.
Diplospirella Bittner	T.								—				
Discina Lamarck	N.		6	?1	?1			?1	—	—	3	—	—
Discinisca Dall	N.		2									2[2]	—
Discinolepis Waagen	N.			—									
Discinopsis Matthew	N.		1	1									
Discolia Fischer and Œhlert	T.												—
Disculina Deslongchamps	T.									—			
Eatonia Hall	T.		9				9[2]						
Eichwaldia Billings	P.		1		1								
Elkania Ford	A.		2	1	1								
Enantiosphen Whidborne	P.						—						
Enteletes Fischer de Waldheim	P.	2	1					1[1]					
Epicyrta Deslongchamps	T.									—			
Etheridgina Œhlert	P.							—					
Eucalathis Fischer and Œhlert	T.												—
Eudesella M. Chalmas	P.									—			
Eudesia King	T.									—			
Eumetria Hall	T.		4					4[1]					
Eunella Hall and Clarke	T.		4				4[3]						
Euractinella Bittner	T.								—				
Fimbriothyris Deslongchamps	T.									—	—	—	
Frenulina Dall	T.												—
Frieleia Dall	T.												—
Glassia Davidson	T.		1		1	—							
Glassina Hall and Clarke	T.					—							
Glossina Phillips	A.	2	13		5[1]	1	3[1]	4[1]					
Glossothyris Douvillé	T.									—	—		
Glottidia Dall	A.												—
Grunewaldtia Tschernyschew	T.					—	—						
Gwynia King	T.												—
Gypidula Hall	P.		14			6	8[2]						
Harttina Hall and Clarke	T.	1	1					1					
Hebertella Hall and Clarke	P.		12		10[5]	2							
Helmersenia Pander	N.				—								
Hemipronites Pander	P.				—								
Hemiptychina Waagen	T.							—	—	—	—		
Hemithyris d'Orbigny	T.		1									1	—
Heterorthis Hall and Clarke	P.		1		1								
Hindella Davidson	T.		2			2[1]							
Hipparionyx Vanuxem	P.		1				1[1]						
Homœospira Hall and Clarke	T.		3			3							
Hustedia Hall and Clarke	T.	1	4					4[1]					
Hyattella Hall and Clarke	T.		2			2[1]							
Hynniphoria Suess	T.									—			
Hypothyris King	T.		3				3[2]						
Iphidea Billings	N.		8	8[3]									
Ismenia King	T.									—			
Juvavella Bittner	T.								—				
Juvavellina Bittner	T.								—				
Karpinskya Tschernyschew	T.						—						

Digitized by Google

TABLE I.—*Brachiopod genera alphabetically arranged, etc.*—Continued.

Genus.	Ordinal rank.	South American species.	North American species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Permian and Carboniferous.	Triassic.	Jurassic.	Cretaceous.	Tertiary.	Recent.
Kayserella Hall and Clarke	P.						—						
Kayseria Davidson	T.						—						
Kingina Davidson	T.		2							—	2		
Koninckella M. Chalmas	T.									—			
Koninckina Suess	T.								—				
Koninckodonta Bittner	T.								—				
Kraussina Davidson	T.												—
Kutorgina Billings	P.		1	1									
Lacazella M. Chalmas	P.									—	—	—	
Lacqueus Dall	T.												—
Lakmina Œhlert	A.			—									
Leiorhynchus Hall	T.		18				15[7]	3					
Leptæna Dalman	P.	1	4		3[2]	1[1]	2[2]	1					
Leptænisca Beecher	P.		3				3[1]						
Leptella Hall and Clarke	P.		2		2[1]								
Leptembolon Mickwitz	A.				—								
Leptobolus Hall	A.		4		4[3]								
Lindstrœmella Hall and Clarke	N.		1				1						
Lingula Brugiere	A.	11	102	?7	36[13]	12[1]	28[5]	17[2]	—	1	3[2]	—	—
Lingulasma Ulrich	A.		2		2[1]								
Lingulella Salter	A.		21	19[2]	3		?1[1]						
Lingulepis Hall	A.		9	9[3]	1								
Lingulodiscina Whitfield	N.		4				1	3[1]					
Lingulobolus Matthew	A.		1	1									
Lingulops Hall	A.		3		2	1							
Linnarsonia Walcott	N.		4	4[2]									
Liothyrina Œhlert	T.											—	—
Lissopleura Whitfield	T.		1				1						
Lycophoria Lahusen	P.					—							
Lyra Cumberland	T.										—		
Lyttonia Waagen	P.							—					
Macandrewia King	T.												—
Magas Sowerby	T.										—		
Magellania Bayle	T.		1							—		1	—
Mannia Dewalque	T.										—	—	
Martinia McCoy	T.		10				7[1]	3[2]	?				
Martiniopsis Waagen	T.							—	?				
Meekella White and St. John	P.		4					4[1]					
Megalanteris Suess	T.		2				2						
Megathyris d'Orbigny	T.									—	—	—	—
Megerlina Deslongchamps	T.												—
Mentzelia Quenstedt	T.									—			
Merista Suess	T.		3				3						
Meristella Hall	T.	1	21				20[9]	1					
Meristina Hall	T.		3			3[2]							
Mesotreta Kutorga	N.				—								
Metaplasia Hall and Clarke	T.		2				2[1]						
Mickwitzia Schmidt	A.			—									
Microthyris Deslongchamps	T.									—	—		
Mimulus Barrande	P.		1			1							
Monobolina Salter	N.				—								

Digitized by Google

TABLE I.—*Brachiopod genera alphabetically arranged, etc.*—Continued.

Genus.	Ordinal rank.	South American species.	North American species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Permian and Carboniferous.	Triassic.	Jurassic.	Cretaceous.	Tertiary.	Recent
Monomorella Billings	A.		9			9[4]							
Muhlfeldtia Bayle	T.												
Neobolus Waagen	A.												
Newberria Hall	T.		4				4						
Nœtlingia Hall and Clarke	P.												
Norella Bittner	T.												
Notothyris Waagen	T.	1											
Nucleatula Bittner	T.												
Nucleospira Hall	T.		7			2[1]	4[3]	1					
Obolella Billings	A.		12	12[4]	2								
Obolus Eichwald	A.		2	2									
Oldhamina Waagen	P.												
Orbicella d'Orbigny	N.												
Orbiculoidea d'Orbigny	N.	2	40		1[1]	5	16[5]	18[6]					
Oriskania Hall and Clarke	T.		1				1						
Orthidium Hall and Clarke	P.		1		1								
Orthis Dalman	P.	6	48	6	23[6]	16[1]	2	1					
Orthoidea Friren	T.												
Orthorhynchula Hall and Clarke	T.		1		1[1]								
Orthostrophia Hall	P.		2			2[1]							
Orthothetes Fischer de Waldheim	P.	2	21			4[1]	12[5]	6[5]					
Orthotichia Hall and Clarke	P.	1											
Orthotrophia Hall and Clarke	P.		1			1							
Parastrophia Hall and Clarke	P.		10		5[2]	5							
Parazyga Hall and Clarke	T.		2				2[1]						
Paterula Barrande	A.		1		1								
Pentactinella Bittner	T.												
Pentagonia Cozzens	T.		1				1[1]						
Pentamerella Hall	P.		9			1	8[2]						
Pentamerus Sowerby	P.		7			7[4]							
Peregrinella Œhlert	T.												
Pexidella Bittner	T.												
Pholidops Hall	N.		17		4[1]	3[2]	10						
Pholidostrophia Hall and Clarke	P.		1				1[1]						
Platidia Costa	T.												
Platystrophia King	P.		6		6[1]	1							
Plectambonites Pander	P.	1	8		3[1]	6[1]							
Plectorthis Hall and Clarke	P.		11		10[2]		1						
Plesiothyris Douville	T.												
Plicigera Bittner	T.												
Polytœchia Hall and Clarke	P.		1		1								
Pomatospirella Bittner	T.												
Porambonites Pander	P.												
Proboscidella Œhlert	P.		1					1					
Productella Hall	P.	1	32				28[9]	6[5]					
Productus Sowerby	P.	16	87					87[27]					
Propygope Bittner	T.												
Protorhyncha Hall and Clarke	T.		3	2	1[1]								
Pseudocrania McCoy	N.												
Pterophloios Gümbel	P.												

Digitized by Google

TABLE I.—*Brachiopod genera alphabetically arranged, etc.*—Continued.

Genus.	Ordinal rank.	South American species.	North American species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Permian and Carboniferous.	Triassic.	Jurassic.	Cretaceous.	Tertiary.	Recent.
Ptychospira Hall and Clarke	T.		1					1					
Pugnax Hall and Clarke	T.		12				3^{2}	9^{1}					
Pygope Link	T.									—			
Rafinesquina Hall and Clarke	P.		21		20^{4}	$!1^{1}$							
Rensselæria Hall	T.		9				9^{2}						
Reticularia McCoy	T.	1	22			2^{1}	10^{1}	10^{4}					
Retzia King	T.	1	6		$!1$		2	$!3$	?				
Rhætina Waagen	T.								—				
Rhinobolus Hall	A.		2			2							
Rhipidomella Œhlert	P.	3	44			8^{2}	24^{7}	13^{5}					
Rhynchonella Fischer de Waldheim	T.	14	104		8^{2}	22^{6}	33^{1}	32^{3}	3	2	3	1	—
Rhynchonellina Gemmellaro	T.								—	—			
Rhynchopora Œhlert	T.		1					1^{1}					
Rhynchora Dalman	T.										—		
Rhynchorina Œhlert	T.										—	—	
Rhynchospira Hall	T.		10			3^{1}	5^{1}	2					
Rhynchotrema Hall	T.		8		7^{6}		1						
Rhynchotreta Hall	T.		1			1^{1}							
Richthofenia Kayser	P.							—					
Rœmerella Hall and Clarke	N.		1				1^{1}						
Romingerina Hall and Clarke	T.		1					1^{1}					
Scaphiocœlia Whitfield	T.	1					—						
Scenidium Hall	P.		5		2^{2}	1	2^{1}						
Schizambon Walcott	N.		4		4								
Schizobolus Ulrich	A.		1				1^{1}						
Schizocrania Hall and Whitfield	N.		5		3^{1}		2						
Schizopholis Waagen	P.			—									
Schizophoria King	P.	1	13			1	9^{5}	3^{3}					
Schizotreta Kutorga	N.		5		4^{2}	1^{1}							
Selenella Hall and Clarke	T.		1				1						
Seminula McCoy	T.	2	16					16^{4}					
Siphonotreta de Verneuil	N.		2		2^{1}	—							
Sphærobolus Matthew	A.		1	1									
Spirifer Sowerby	T.	23	177			15^{7}	92^{22}	70^{19}					
Spiriferina d'Orbigny	T.	4	19					15^{7}	4	—			
Spirigerella Waagen	T.	1						—					
Spondylobolus McCoy	A.				—								
Streptis Davidson	P.		1			1^{1}							
Streptorhynchus King	P.	1	2					2					
Stricklandinia Billings	P.		17			16^{3}		$!1$					
Stringocephalus Defrance	T.		1				1^{1}						
Strophalosia King	P.	1	12				5^{2}	7					
Stropheodonta Hall	P.	1	58			12^{2}	46^{17}						
Strophomena Blainville	P.	1	47		31^{11}	13	2	1					
Strophonella Hall	P.		16			4^{2}	12^{5}						
Suessia Deslongchamps	T.									—			
Syntrophia Hall and Clarke	P.		7	6^{1}	1								
Syringothyris Winchell	T.		9					9^{2}					
Terebratalia Beecher	T.												—

Digitized by Google

TABLE I.—*Brachiopod genera alphabetically arranged, etc*—Continued.

Genus.	Ordinal rank.	South American species.	North American species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Permian and Carboniferous.	Triassic.	Jurassic.	Cretaceous.	Tertiary.	Recent.
Terebratella d'Orbigny	T.	.....	5	.....	.....	.....	.....	.....	.....	—	5	—	—
Terebratula Llhwyd	T.	20	22	.....	.....	.....	3[1]	10	3	2	2	2	.....
Terebratulina d'Orbigny	T.	.....	6	.....	.....	.....	.....	.....	.....	—	4	2	—
Terebratuloidea Waagen	T.	.....	.....	.....	.....	.....	.....	—	.....	.....	.....	.....	.....
Tetractinella Bittner	T.	.....	.....	.....	.....	.....	.....	.....	—	.....	.....	.....	.....
Thecidella M. Chalmas	P.	.....	.....	.....	.....	.....	.....	.....	.....	—	.....	.....	.....
Thecidia Defrance	P.	.....	.....	.....	.....	.....	.....	.....	?	.....	—	.....	.....
Thecidiopsis M. Chalmas	P.	.....	.....	.....	.....	.....	.....	.....	.....	.....	—	.....	.....
Thecocyrtella Bittner	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Thecospira Zügmeyer	T.	.....	.....	.....	.....	.....	.....	.....	—	—	.....	.....	.....
Thysanotos Mickwitz	A.	.....	.....	.....	—	.....	.....	.....	.....	.....	.....	.....	.....
Tomasina Hall and Clarke	A.	.....	.....	.....	—	.....	.....	.....	.....	.....	.....	.....	.....
Torynifer Hall and Clarke	T.	.....	1	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
Trematis Sharpe	N.	.....	14	.....	14[2]	.....	.....	.....	.....	.....	.....	.....	.....
Trematobolus Matthew	N.	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....
Trematospira Hall	T.	.....	12	.....	.....	1	11[1]	.....	.....	.....	.....	.....	.....
Trigeria (Bayle) Hall and Clarke	T.	2	3	.....	.....	.....	3	.....	.....	.....	.....	.....	.....
Trigonosemus Koenig	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	—	.....	.....
Trimerella Billings	A.	.....	5	.....	.....	5[3]	.....	.....	.....	.....	.....	.....	.....
Triplecia Hall	P.	.....	7	.....	5	2	.....	.....	.....	.....	.....	.....	.....
Tropidoleptus Hall	T.	.....	2	.....	.....	.....	2[1]	.....	.....	.....	.....	.....	.....
Uncinella Waagen	T.	.....	.....	.....	.....	.....	.....	—	.....	.....	.....	.....	.....
Uncinulus Bayle	T.	.....	8	.....	.....	1[1]	7[3]	.....	.....	.....	.....	.....	.....
Uncites Defrance	T.	.....	.....	.....	.....	.....	—	.....	.....	.....	.....	.....	.....
Verneuilia Hall and Clarke	T.	.....	.....	.....	.....	.....	—	—	.....	.....	.....	.....	.....
Vitulina Hall	T.	.....	1	.....	.....	.....	1[1]	.....	.....	.....	.....	.....	.....
Volborthia von Möller	N.	.....	.....	—	.....	.....	.....	.....	.....	.....	.....	.....	.....
Whitfieldella Hall and Clarke	T.	.....	13	.....	.....	11[6]	2	.....	.....	.....	.....	.....	.....
Wilsonia Kayser	T.	.....	4	.....	.....	4[2]	1	.....	.....	.....	.....	.....	.....
Zeilleria Bayle	T.	.....	.....	.....	.....	.....	.....	.....	—	.....	.....	.....	.....
Zellania Moore	T.	.....	.....	.....	.....	.....	.....	.....	.....	—	.....	.....	.....
Zugmeyeria Waagen	T.	.....	.....	.....	.....	.....	.....	.....	—	.....	.....	.....	.....
Zygospira Hall	T.	.....	14	.....	10[5]	3	1	.....	.....	.....	.....	.....	.....
Total	....	154	1,894	103	311	320	655	482	10	5	22	9	32

Digitized by Google

TABLE II.—*North American Paleozoic representation of the orders, superfamilies, and families, geologically arranged.*

Order, superfamily, and family.	Number of species.	Number of genera.	Cambrian species.	Ordovician species.	Silurian species.	Devonian species.	Permian and Carboniferous species.
Order Atremata	196	19	57	60	31	30	21
Superf. Obolacea	43	9	22	6	17	.....	.....
Fam. Paterinidæ	8	1	8[2]	.....	.....	.....	.....
Obolidæ	17	4	16[4]	3	.....	.....	.....
Trimerellidæ	20	4	.....	3[1]	17[8]	.....	.....
Superf. Lingulacea	153	10	35	54	14	30	21
Fam. Lingulellidæ	35	4	28[6]	6[3]	.....	1[1]	.....
Lingulidæ	113	4	7	41[14]	13[1]	29[5]	21[3]
Lingulasmatidæ	5	2	.....	4[1]	1	.....	.....
Order Neotremata	153	21	20	44	21	42	26
Superf. Discinacea	99	18	19	30	8	20	22
Fam. Trematidæ	24	4	.....	17[2]	2	2[1]	3[1]
Discinidæ	50	5	1	6[3]	6[1]	18[6]	19[6]
Acrotretidæ	16	5	15[5]	1[1]	.....	.....	.....
Siphonotretidæ	7	3	1	6[1]	.....	.....	.....
Superf. Craniacea	54	3	1	14	13	22	4
Fam. Craniidæ	54	3	1	14[4]	13[3]	22[4]	4[1]
Order Protremata	735	62	22	173	161	210	179
Superf. Thecacea	608	45	16	152	96	185	169
Fam. Kutorginidæ	1	1	1	.....	.....	.....	.....
Eichwaldiidæ	6	2	.....	1	5[1]	.....	.....
Billingsellidæ	12	1	9[2]	2	1	.....	.....
Strophomenidæ	211	19	.....	65[19]	48[10]	77[21]	26[6]
Productidæ	186	9	.....	.....	5[1]	60[24]	125[46]
Orthidæ	192	13	6	84[32]	37[7]	48[16]	18[9]
Superf. Trullacea	127	17	6	21	65	25	10
Fam. Clitambonitidæ	9	3	.....	6[3]	1	2[1]	.....
Syntrophiidæ	7	1	6[1]	1	.....	.....	.....
Porambonitidæ	24	3	.....	14[4]	10[2]	.....	.....
Pentameridæ	87	10	.....	.....	54[12]	23[5]	10[2]
Order Telotremata	762	76	2	20	109	369	269
Superf. Rostracea	197	14	2	18	37	94	49
Fam. Protorhynchidæ	3	1	2	1[1]	.....	.....	.....
Rhynchonellidæ	194	13	.....	17[10]	37[12]	94[28]	49[9]
Superf. Terebratulacea	79	19	.....	.....	1	50	30
Fam. Centronellidæ	30	8	.....	.....	.....	26[6]	4[2]
Terebratulidæ	47	10	.....	.....	1	22[11]	26[7]
Tropidoleptiidæ	2	1	.....	.....	.....	2[1]	.....
Superf. Spiriferacea	486	43	.....	2	71	225	190
Fam. Atrypidæ	45	8	.....	.....	14[7]	18	14[6]
Spiriferidæ	278	11	.....	1[1]	24[13]	138[48]	115[35]
Athyridæ	163	24	.....	1	33[14]	69[23]	61[16]

Digitized by Google

TABLES OF NORTH AND SOUTH AMERICAN SPECIES GEOLOGICALLY ARRANGED.

TABLE III, CAMBRIAN.—TABLE IV, ORDOVICIAN.—TABLE V, SILURIAN.—TABLE VI, DEVONIAN.—TABLE VII, CARBONIFEROUS AND PERMIAN.—TABLE VIII, MESOZOIC.—TABLE IX, CENOZOIC AND RECENT.—TABLE X, SOUTH AMERICAN FOSSIL BRACHIOPODA.

TABLE III.—*Cambrian Brachiopoda.*

[Species preceded by an asterisk (*) are found in the Ordovician also.]

Species.	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.
Acrothele (?) dichotoma Walcott	×		
Acrothele matthewi (Hartt)		×	
Acrothele matthewi costata Matthew		×	
Acrothele matthewi lata Matthew		×	
Acrothele matthewi prima Matthew		×	
Acrothele subsidua (White)	×	×	
Acrotreta baileyi Matthew		×	
Acrotreta gemma Billings	×	×	×
Acrotreta gemma depressa Walcott		×	
Acrotreta gemmula Matthew		×	
Acrotreta microscopica (Shumard)		×	
Billingsella alberta (Walcott)		×	
Billingsella billingsi (Hartt)		×	
Billingsella coloradoensis (Shumard)			×
Billingsella festinata (Billings)	×		
Billingsella latourensis (Matthew)		×	
Billingsella orientalis (Whitfield)	×		
Billingsella quacoensis (Matthew)		×	
Billingsella transversa (Walcott)	×		
Billingsella whitfieldi (Walcott)	×		
Botsfordia pulchra Matthew		×	
Crania (?) columbiana Walcott		×	
Dalmanella melita (Hall and Whitfield)			×
Discina (?) inutilis Hall			×
Discinopsis gulielmi Matthew		×	
Elkania desiderata (Billings)			×
Iphidea bella Billings	×		
Iphidea labradorica (Billings)	×		
Iphidea labradorica swantonensis (Walcott)	×		
Iphidea ornatella Hall and Clarke			×
Iphidea pannula (White)	×	×	
Iphidea prospectensis (Walcott)	×		
Iphidea sculptilis (Meek)			×
Iphidea stissingensis (Dwight)		×	
Kutorgina cingulata Billings	×		
Kutorgina (?) pterinoides Matthew		×	
Lingula (?) calumet N. H. Winchell			
Lingula (?) elliptica Emmons	?		
Lingula (?) manticula White			×
Lingula (?) mosia Hall			×
Lingula (?) murrayi Billings			×
*Lingula quebecensis Billings			×
Lingula (?) striata Emmons	×?		
Lingulella ampla Owen		×	
Lingulella aurora Hall			×

Digitized by Google

TABLE III.—*Cambrian Brachiopoda*—Continued.

Species.	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.
Lingulella (?) billingsana (Whiteaves)			×
Lingulella (?) cælata (Hall)	×		
Lingulella dawsoni Matthew		×	
Lingulella ella (Hall and Whitfield)	×	×	
Lingulella granvillensis Walcott	×		
Lingulella (?) inflata Matthew		×	
Lingulella (?) inflata ovalis Matthew		×	
*Lingulella irene (Billings)			×
Lingulella lævis Matthew			×
Lingulella lamborni Meek			×
Lingulella linguloides Matthew		×	
Lingulella macconelli Walcott		×	
Lingulella martinensis Matthew		×	
*Lingulella minuta Hall and Whitfield			×
Lingulella radula Matthew		×	
Lingulella starri Matthew		×	
Lingulella starri minor Matthew			×
Lingulella stoneana Whitfield			×
Lingulella winona Hall		×	
Lingulepis acuminata (Conrad)			×
Lingulepis acutangula (Roemer)			×
Lingulepis cuneolus Whitfield			×
*Lingulepis (?) mæra Hall and Whitfield			×
Lingulepis matinalis Hall			×
Lingulepis pinniformis Owen			×
Lingulepis prima (Hall)			×
Lingulepis primæformis Whitfield			×
Linnarsonia belti Davidson ?			×
Linnarsonia misera (Billings)		×	
Linnarsonia pretiosa (Billings)			×
Linnarsonia sagittalis taconica Walcott	×	×	
Linnarsonia transversa (Hartt)		×	
Obolella atlantica Walcott	×		
Obolella chromatica Billings	×		
Obolella circe Billings	×		
Obolella crassa (Hall)	×		
*Obolella (?) discoidea Hall and Whitfield			×
Obolella gemma Billings	×		
Obolella (?) gemmula Matthew			×
*Obolella (?) ida Billings			×
Obolella minuta (Hall and Whitfield)			×
Obolella nana Meek and Hayden		×	
Obolella nitida Ford	×		
Obolella pectenoides Whitfield			×
Obolella polita Hall		×	
Obolus (?) major Matthew	×		
Obolus (?) murrayi Billings		×?	
Obolus pristinus Matthew		×	
Obolus pulcher Matthew			×
Obolus refulgens Matthew			×
Orbicula (?) excentrica Emmons	×?		
Orthis (?) apicalis Billings			×
Orthis (?) eurekensis Walcott			×
Orthis (?) highlandensis Walcott	×		

Digitized by Google

TABLE III.—*Cambrian Brachiopoda*—Continued.

Species.	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.
Orthis (?) lenticularis Wahlenberg			×
Orthis (?) lenticularis atrypoides Matthew			×
Orthis (?) lenticularis lyncioides Matthew			×
Orthis (?) lenticularis strophomenoides Matthew			×
Orthis (?) remnichia N. H. Winchell			×
Orthis (?) salemensis Walcott	×		
Orthis (?) sandbergi N. H. Winchell			×
Orthisina (?) johannensis Matthew			×
Protorhyncha (?) antiquata (Billings)	×		
Protorhyncha (?) minor (Walcott)	×		
Syntrophia arachne (Billings)			×
Syntrophia arethusa (Billings)			×
Syntrophia (?) armanda (Billings)			×
Syntrophia barabuensis (A. Winchell)			×
Syntrophia calcifera (Billings)			×
Syntrophia primordialis (Whitfield)			×
Trematobolus insignis Matthew		×	
Number of Cambrian species, 116.			
Number of species in each division	31	39	51
Number of species common to the Lower and the other divisions of the Cambrian		5	1
Number of species common to the Middle and the other divisions of the Cambrian	5		1
Number of species common to the Cambrian and Ordovician system, 6.			
Number of species passing from each division into the Ordovician	0	0	6

Digitized by Google

TABLE IV.—*Ordovician Brachiopoda.*

[Bi = Birdseye; BR = Black River; Ci = Cincinnati and Lorraine; EO = Eoordovician; MO = Mesoordovician; NO = Neoordovician; T = Trenton; U = Utica. Species preceded by an asterisk (*) are found in the Silurian also; by an obelisk (†), in the Cambrian.]

Species.	Eoordovician.		Mesoordovician.	Neoordovician.
	Calciferous.	Chasy.	Trenton, Black River, Birdseye.	Cincinnati, Utica.
Billingsella (?) grandæva (Billings)	×			
Billingsella (?) primordialis (Whitfield)	×			
Camarella ambigua (Hall)			T	
Camarella breviplicata Billings	×			
Camarella (?) costata Billings	×			
Camarella longirostrum Billings		×		
Camarella panderi Billings			BR	
Camarella parva Billings	×			
Camarella polita Billings	×			
Camarella varians Billings	×	×		
Camarella volborthi Billings			BR	
Camarotœchia plena Hall		×		
Cataxyga erratica Hall				Ci
Cataxyga headi (Billings)				U, Ci
Clitambonites (?) borealis (Castelnau)			T	
Clitambonites diversa (Shaler)			T	Ci
Clitambonites diversa altissima Winchell and Schuchert			T	
Clitambonites plana retroflexa de Verneuil	× ?			
Conotreta rusti Walcott			T	
Crania albersi Miller and Faber				U
Crania (?) deformis (Hall)		×		
Crania dyeri Miller				U
Crania granulosa N. H. Winchell			T	
Crania lælia Hall				U, Ci
Crania (?) reversa Sardeson		×		
Crania scabiosa Hall				U, Ci
Crania setigera Hall			T	Ci
Crania socialis Ulrich				U
Crania trentonensis Hall			T	
Craniella (?) ulrichi Hall and Clarke			T	
Cyclospira bisulcata (Emmons)			T	
Dalmanella amœna N. H. Winchell			T	
Dalmanella bellula (James) Meek sp				Ci
Dalmanella crispata (Emmons)				Ci
Dalmanella electra (Billings)	×			
Dalmanella electra major Matthew	×			
Dalmanella electra lævis Matthew	×			
Dalmanella (?) evadne (Billings)	×			
Dalmanella hamburgensis (Walcott)			T	
Dalmanella macleodi (Whitfield)	×			
Dalmanella (?) plicifera (Hall)		×		
Dalmanella pogonipensis (Hall and Whitfield)	×			
Dalmanella stonensis (Safford)			T	
Dalmanella subæquata (Conrad)			T	
Dalmanella subæquata circularis N. H. Winchell			T	
Dalmanella subæquata conradi N. H. Winchell			T	
Dalmanella subæquata gibbosa Billings		×	BR, T	
Dalmanella subæquata perveta (Conrad)			T	
Dalmanella tersus (Sardeson)				Ci

Digitized by Google

TABLE IV.—*Ordovician Brachiopoda*—Continued.

Species.	Eoordovician.		Mesoordovician.	Neoordovician.
	Calciferous.	Chazy.	Trenton, Black River, Birdseye.	Cincinnati, Utica.
Dalmanella testudinaria (Dalman)		×	Bi, BR, T	U, Ci
Dalmanella testudinaria emacerata Hall				U
Dalmanella testudinaria meeki (Miller)				Ci
Dalmanella testudinaria multisecta (James) Meek sp				U
Dinobolus canadensis (Billings)			BR, T	
Dinobolus magnificus (Billings)			BR, T	
Dinobolus (?) parvus Whitfield			T	
Dinorthis deflecta Conrad			T	
Dinorthis fontinalis (White)	×			
Dinorthis iphigenia (Billings)			T	
Dinorthis meedsi Winchell and Schuchert			T	
Dinorthis meedsi germana Winchell and Schuchert			T	
Dinorthis pectinella (Emmons)			T	
Dinorthis pectinella sweeneyi N. H. Winchell			T	
Dinorthis platys (Billings)		×		
Dinorthis porcata (McCoy)			T	Ci
Dinorthis proavita Winchell and Schuchert				Ci
Dinorthis retrorsa (Salter)			T	Ci
Dinorthis subquadrata Hall				Ci
Discina (?) sublamellosa Ulrich				Ci
Eichwaldia subtrigonalis Billings			T	
Elkania ambigua (Walcott)	×			
Glassia romingeri Hall and Clarke			T	
Glossina crassa (Hall)			T	
Glossina cyane (Billings)	×			
Glossina deflecta Winchell and Schuchert			T	Ci
Glossina huributi N. H. Winchell			T	
Glossina trentonensis (Conrad)			T	U
Hebertella battis (Billings)	×			
Hebertella bellarugosa (Conrad)			T	
Hebertella borealis (Billings)		×	BR, T	
Hebertella imperator (Billings)		×		
Hebertella insculpta Hall				Ci
Hebertella lonensis (Walcott)	×			
Hebertella maria (Billings)				Ci
Hebertella occidentalis Hall				Ci
Hebertella occidentalis sinuata Hall				Ci
Heterorthis clytie Hall			T	
Leptæna charlottæ Winchell and Schuchert			T	
*Leptæna rhomboidalis (Wilckens)			T	U, Ci
Leptæna unicostata Meek and Worthen				Ci
Leptella sordida (Billings)	×			
Leptella decipiens (Billings)	×			
Leptobolus grandis Matthew	×			
Leptobolus insignis Hall				U
Leptobolus lepis Hall				U
Leptobolus occidentalis Hall				U
Lingula æqualis Hall			T	
Lingula belli Billings		×		
Lingula beltrami Winchell and Schuchert				Ci
Lingula bisulcata Ulrich				U
Lingula briseis Billings			T	

Digitized by Google

TABLE IV.—*Ordovician Brachiopoda*—Continued.

Species.	Ecordovician.		Mesoordovician.	Neoordovician.
	Calciferous.	Chasy.	Trenton, Black River, Birdseye.	Cincinnati, Utica.
Lingula (?) canadensis Billings			T	Ci
Lingula cincinnatiensis Hall and Whitfield				Ci
Lingula clathrata Winchell and Schuchert			T	
Lingula cobourgensis Billings			T	
Lingula covingtonensis Hall and Whitfield			T	
Lingula curta Conrad			T	U
Lingula (?) dolata Sardeson	×			
Lingula elderi Whitfield			T	Ci
Lingula elongata Hall			T	
Lingula eva Billings			BR	
Lingula forbesi Billings				Ci
Lingula howleyi Matthew	×			
Lingula huronensis Billings		×		
Lingula iole Billings	×			
Lingula iowensis Owen			T	
Lingula iris Billings	×			
Lingula kingstonensis Billings			BR	
Lingula lyelli Billings		×		
Lingula mantelli Billings	×			
Lingula modesta Ulrich			T	U, Ci
Lingula morsii N. H. Winchell		×		
Lingula nympha Billings	×			
Lingula obtusa Hall			T	U
Lingula papillosa Emmons			T	
Lingula perryi Billings		× ?		
Lingula philomela Billings			T	C.
Lingula progne Billings			T	U
†Lingula quebecensis Billings	×		T	Ci
Lingula rectilateralis Emmons			T	
Lingula riciniformis Hall			T	
Lingula riciniformis galenensis Winchell and Schuchert			T	
Lingula vanhorni Miller			T	Ci
Lingula whitfieldi Ulrich				Ci
Lingulasma galenensis Winchell and Schuchert			T	
Lingulasma schucherti Ulrich				Ci
Lingulella (?) cuneata Matthew	×			
†Lingulella irene (Billings)	×			
†Lingulella minuta Hall and Whitfield	×			
Lingulella roberti Matthew	×			
Lingulella selwyni Matthew	×			
†Lingulepis (?) mæra Hall and Whitfield	×			
Lingulobolus affinis Billings	×			
Lingulobolus affinis cuneata Matthew	×			
Lingulops norwoodi (James)			T	
Lingulops whitfieldi Hall				U
†Obolella (?) discoidea Hall and Whitfield	×			
†Obolella (?) ida Billings	×			
Orbiculoidea lamellosa Hall			T	Ci
Orbiculoidea tenuistriata (Ulrich)				U
Orthidium gemmicula (Billings)	×			
Orthis (?) acuminata Billings		×		
Orthis carausii Salter	×			

Digitized by Google

TABLE IV.—*Ordovician Brachiopoda*—Continued.

Species.	Eoordovician.		Mesoordovician.	Neoordovician.
	Calciferous.	Chazy.	Trenton, Black River, Birdseye.	Cincinnati, Utica.
Orthis (?) centrilineata Hall				Ci
Orthis corinna Billings	×			
Orthis costalis Hall		×		
Orthis (?) delicatula Billings	× ?			
Orthis (?) desmoplcura Meek	×			
Orthis (?) eudocia Billings	×			
Orthis euryone Billings	×			
Orthis hippolyte Billings	×			
Orthis (?) holstoni (Safford) Hall			T	
Orthis (?) leptænoides Emmons			T	
Orthis menapiæ Hicks	×			
Orthis (?) minna Billings	×			
Orthis (?) morrowensis James				Ci
Orthis (?) mycale Billings	×			
Orthis panderiana Hall	×			
Orthis (?) pigra Billings		×		
Orthis (?) porcia Billings		×		
Orthis (?) pumila Ulrich				Ci
Orthis (?) saffordi Hall and Clarke			T	
Orthis (?) sola Billings				Ci
Orthis tricenaria Conrad			T	
Orthis (?) tritonia Billings	×			
Orthorhynchula linneyi (James)				Ci
Parastrophia divergens Hall and Clarke				Ci
Parastrophia hemiplicata Hall			T	
Parastrophia hemiplicata rotunda (Winchell and Schuchert)			T	
Parastrophia obscura (Hall and Whitfield)	×			
Parastrophia scofieldi (Winchell and Schuchert)			T	
Paterula amii Schuchert	×			
Pholidops cincinnatiensis Hall				Ci
Pholidops subtruncata Hall				Ci
Pholidops trentonensis Hall			T	
Pholidops trentonensis minor Winchell and Schuchert			T	
Platystrophia acuminata James				Ci
Platystrophia acutilirata (Conrad)				Ci
*Platystrophia biforata (Schlotheim)		×	BR, T	U, Ci
Platystrophia crassa (James)				Ci
Platystrophia laticostata Meek				Ci
Platystrophia lynx (Eichwald)				Ci
Plectambonites gibbosa Winchell and Schuchert			T	
Plectambonites plicatella (Ulrich)				U
*Plectambonites sericea (Sowerby)			BR, T	U, Ci
Plectorthis æquivalvis Hall				Ci
Plectorthis dichotoma Hall				Ci
Plectorthis ella Hall				Ci
Plectorthis fissicosta Hall				Ci
Plectorthis jamesi Hall				Ci
Plectorthis kankakensis (McChesney)				Ci
Plectorthis plicatella Hall			T	U, Ci
Plectorthis sectostriata (Ulrich)				Ci
Plectorthis triplicatella (Meek)				Ci

Digitized by Google

TABLE IV.—*Ordovician Brachiopoda*—Continued.

Species.	Eoordovician.		Mesoordovician.	Neoordovician.
	Calciferous.	Chazy.	Trenton, Black River, Birdseye.	Cincinnati, Utica.
Plectorthis whitfieldi (N. H. Winchell)				Ci
Polytœchia apicalis (Whitfield)	×			
Protorhyncha dubia Hall		×		
Rafinesquina alternata (Conrad) Emmons			BR, T	U, Ci
Rafinesquina alternata alternistriata Hall				Ci
Rafinesquina alternata fracta (Meek)				Ci
Rafinesquina alternata loxorhytis (Meek)				Ci
Rafinesquina alternata nasuta (Conrad)				Ci
Rafinesquina (?) atava (Matthew)	×			
* Rafinesquina ceres (Billings)				Ci
Rafinesquina deltoidea (Conrad)			T	U
Rafinesquina fasciata Hall		×		
Rafinesquina imbrex (Pander)				Ci
Rafinesquina incrassata (Hall)		×	BR	
Rafinesquina kingi (Whitfield)				Ci
Rafinesquina lata Whiteaves				Ci
Rafinesquina mesacosta (Shumard)			T?	
Rafinesquina minnesotensis (N. H. Winchell)			T	
Rafinesquina minnesotensis inquassa (Sardeson)			T	
Rafinesquina nitens (Billings)				Ci
Rafinesquina squamula (James)				U, Ci
Rafinesquina tenuilineata (Conrad)			T	
Rafinesquina ulrichi (James)				U
Retzia (?) granulifera (Meek)				Ci
Rhynchonella (?) acutirostris Hall		×		
Rhynchonella (?) anticostiensis Billings				Ci
Rhynchonella (?) corinthia Billings	×			
* Rhynchonella (?) janea Billings				Ci
Rhynchonella (?) neenah Whitfield				Ci
Rhynchonella (?) orientalis Billings		×		
Rhynchonella (?) sordida Hall			T	
Rhynchonella (?) subtrigonalis Hall			T	
Rhynchotrema ainslæi (N. H. Winchell)			T	
Rhynchotrema capax (Conrad)				Ci
Rhynchotrema dentata (Hall)			T	Ci
Rhynchotrema inæquivalvis (Castelnau)			T	
Rhynchotrema inæquivalvis laticostata Winchell and Schuchert			T	
Rhynchotrema ottawaensis (Billings)			T	
Rhynchotrema perlamellosa (Whitfield)				Ci
Scenidium anthonensis Sardeson			T	
Scenidium (?) merope (Billings)			T	Ci
Schizambon (?) dodgii Winchell and Schuchert			T	
Schizambon (?) fissus canadensis Ami				U
Schizambon (?) lockii Winchell and Schuchert				Ci
Schizambon typicalis Walcott	×			
Schizocrania filosa Hall			T	U, Ci
Schizocrania (?) rudis Hall			T	
Schizocrania schucherti Hall and Clarke			T	
Schizotreta conica (Dwight)			T	
Schizotreta minutula Winchell and Schuchert				Ci
Schizotreta ovalis Hall and Clarke			T	

Digitized by Google

TABLE IV.—*Ordovician Brachiopoda*—Continued.

Species.	Eoordovician.		Mesoordovician.	Neoordovician.
	Calciferous.	Chazy.	Trenton, Black River, Birdseye.	Cincinnati, Utica.
Schizotreta pelopea (Billings)			T	Ci
Siphonotreta (?) micula McCoy	×			
Siphonotreta (?) minnesotensis Hall and Clarke			T	
Sphærobolus spissus Billings	×			
Strophomena approximata (James)				Ci
Strophomena (?) arethusa Billings				Ci
Strophomena billingsi Winchell and Schuchert			T	
Strophomena cardinale (Whitfield)				Ci
Strophomena conradi Hall			T	
Strophomena (?) declivis James				Ci
Strophomena emaciata Winchell and Schuchert			T	
Strophomena fluctuosa Billings				U
Strophomena hallii Miller				Ci
Strophomena hecuba Billings				Ci
Strophomena (?) imbecilis Billings	× ?			
Strophomena incurvata (Shepard)			T	
Strophomena lævis Emmons			Bl	
Strophomena (?) minor (Walcott)	×			
Strophomena neglecta (James)				Ci
Strophomena neglecta acuta Winchell and Schuchert				Ci
Strophomena nutans Meek				Ci
Strophomena planoconvexa Hall				Ci
Strophomena planodorsata Winchell and Schuchert				Ci
Strophomena rugosa (Rafinesque) Blainville				Ci
Strophomena rugosa subtenta Hall				Ci
Strophomena scofieldi Winchell and Schuchert			T	
Strophomena septata Winchell and Schuchert			T	
Strophomena sinuata Meek				Ci
Strophomena sulcata (Verneuil)				Ci
Strophomena thalia Billings			T	
Strophomena trentonensis Winchell and Schuchert			T	
Strophomena trilobata (Owen)			T	
Strophomena vetusta James				Ci
Strophomena winchelli Hall			T	
Strophomena wisconsinensis Whitfield				Ci
Syntrophia lateralis (Whitfield)	×			
Trematis crassipuncta Ulrich				Ci
Trematis (?) dyeri Miller				Ci
Trematis fragilis Ulrich			T	
Trematis huronensis Billings			BR	
Trematis millepunctata Hall				U, Ci
Trematis montrealensis Billings			T	
Trematis oblata Ulrich				U, Ci
Trematis ottawaensis Billings			T	Ci
Trematis punctostriata Hall				Ci
Trematis (?) pustulosa Hall				Ci
Trematis quincuncialis Miller and Dyer				Ci
Trematis reticularis Miller				Ci
Trematis terminalis Emmons			T	
Trematis umbonata Ulrich				Ci
Triplecia cuspidata Hall			T	
Triplecia extans (Emmons)			T	

Digitized by Google

TABLE IV.—*Ordovician Brachiopoda*—Continued.

Species.	Eoordovician.		Mesoordovician.	Neoordovician.
	Calciferous.	Chazy.	Trenton, Black River, Birdseye.	Cincinnati, Utica.
Triplecia nucleus Hall			T	
Triplecia (?) radiata Whitfield	×			
Triplecia ulrichi Winchell and Schuchert				Ci
Zygospira cincinnatiensis Meek				Ci
Zygospira concentrica Ulrich				Ci
Zygospira deflecta (Hall)			T	
Zygospira exigua (Hall)			T	
Zygospira kentuckiensis James				Ci
Zygospira modesta Hall				U, Ci
Zygospira nicoletti Winchell and Schuchert			T	
Zygospira putilla Hall and Clarke				Ci
Zygospira recurvirostra (Hall)			T	
Zygospira saffordi Winchell and Schuchert			T	
Number of Ordovician species, 319.				
Number of species in each division	63	26	128	136
Number of species common to the Calciferous and the other divisions		1	0	1
Number of species common to the Chazy and the other divisions	1		5	2
Number of species common to the Trenton and the other divisions	1	5		27
Number of species common to the Cincinnati and the other divisions	1	2	27	
Species common to the Ordovician and Silurian systems, 5.				
Number of species passing from each division into the Silurian	0	1	3	5

Digitized by Google

TABLE V.—*Silurian Brachiopoda.*

[A = Anticosti; Ar = Arisaig; Cl = Clinton; Gu = Guelph; MS = Mesosilurian; N = Niagara; NS = Neosilurian; Te = Tentaculite and Coralline; W = Waterlime. Species preceded by an asterisk (*) are found in the Devonian also; by an obelisk (†), in the Ordovician.]

Species.	Eosilurian.	Mesosilurian.		Neosilurian.
	Medina.	Anticosti, Clinton.	Guelph, Arisaig, Niagara.	Tentaculite, Waterlime.
Anastrophia brevirostris (Sowerby) Hall			N	
Anastrophia internascens Hall			N	
Anastrophia interplicata (Hall)			N	
Anoplotheca hemispherica (Sowerby)		Cl		
Anoplotheca planoconvexa (Hall)		Cl		
Anoplotheca plicatula (Hall)		Cl		
Athyris (?) solitaria Billings		A		
Athyris (?) tumidula Billings		A		
Athyris (?) turgida Shaler		A		
Atrypa (?) gibbosa Hall		Cl		
Atrypa (?) lara (Billings)		A		
Atrypa laticorrugata Foerste		Cl		
Atrypa marginalis (Dalman)			N	
Atrypa nodostriata Hall		Cl	N	
Atrypa phoca (Salter)			MS	
*Atrypa reticularis (Linnæus)		Cl, A	N	
Atrypa reticularis niagarensis Nettelroth			N	
Atrypa rugosa Hall			N	
Atrypina clintoni Hall and Clarke		Cl		
Atrypina disparilis Hall			N	
Atrypina intermedia Hall			Ar	
Billingsella (?) laurentina (Billings)		A		
Bilobites acutilobus (Ringueberg)			N	
Bilobites bilobus (Linnæus)			N	
Camarella lenticularis Billings		A		
Camarotœchia (?) acinus Hall			N	
Camarotœchia (?) acinus convexa (Foerste)		Cl		
Camarotœchia æquiradiata Hall		Cl		
Camarotœchia fringilla Billings		A		
Camarotœchia glacialis Billings		A		
Camarotœchia (?) indianensis Hall			N	
Camarotœchia (?) neglecta Hall		Cl	N	
Camarotœchia (?) obtusiplicata Hall			N	
Camarotœchia (?) whitii Hall			N	
Capellinia mira Hall and Clarke			N	
Chonetes cornuta Hall		Cl		
Chonetes nova-scotica Hall			Ar, N	
Chonetes striatella (Dalman)			N ?	
Chonetes tenuistriata Hall			Ar	
Chonetes undulata Hall			N	
Clintonella vagabunda Hall and Clarke		Cl		
Clorinda arcuosa (McChesney)			N	
Clorinda areyi (Hall and Clarke)		Cl		
Clorinda barrandii (Billings)		A		
Clorinda fornicata (Hall)		Cl	N	
Clorinda ventricosa (Hall)			N	
Conchidium biloculare Linnæus			MS	
Conchidium colletti Miller				W
Conchidium crassiradiatum (McChesney)			N	

Digitized by Google

TABLE V.—*Silurian Brachiopoda*—Continued.

Species.	Ea-silurian.	Mesosilurian.		Neosilurian.
	Medina.	Anticosti, Clinton.	Guelph, Arisaig, Niagara.	Tentaculite, Waterlime.
Conchidium crassiplicum Hall and Clarke			N	
Conchidium decussatum (Whiteaves)			N	
Conchidium exposneus Hall and Clarke			N	
Conchidium georgiæ Hall and Clarke		Cl		
Conchidium greenii Hall and Clarke			N	
Conchidium knappi (Hall and Whitfield)			N	
Conchidium laqueatum (Conrad)			N	
Conchidium littoni (Hall)			N	
Conchidium multicostatum (Hall)			N	
Conchidium nysius (Hall and Whitfield)			N	
Conchidium obsoletum Hall and Clarke			N	
Conchidium occidentale Hall			Gu	
Conchidium scoparium Hall and Clarke			Gu	
Conchidium tenuicostatum (Hall and Whitfield)			N	
Conchidium unguiforme (Ulrich)			N	
Crania acadiensis Hall			Ar	
Crania anna Spencer			N	
Crania dentata Ringueberg			N	
Crania dubia Foerste		Cl		
Crania gracilis Ringueberg			N	
Crania setifera Hall			N	
Crania siluriana Hall			N	
Crania spinigera Hall			N	
Craniella (?) clintonensis Foerste		Cl		
Cyclospira (?) sparsiplica Foerste		Cl		
Cyrtia exporrecta (Wahlenberg)			N	
Cyrtia meta Hall		Cl	N	
Cyrtia myrtia Billings		A	N	
Cyrtina pyramidalis (Hall)			N	
Dalmanella arcuaria Hall and Clarke			N	
Dalmanella elegantula (Dalman)		Cl	N	
Dalmanella elegantula parva (Foerste)		Cl		
Dalmanella parva de Verneuil		A		
Delthyris (?) rugicosta (Hall)			Ar	
Delthyris sulcata Hisinger			N	
Dictyonella anticostiensis Billings		A		
Dictyonella concinna Hall			N	
Dictyonella corallifera Hall			N	
Dictyonella gibbosa Hall			N	
Dictyonella reticulata Hall			N	
Dinobolus conradi Hall			N	
Glossina perovata (Hall)		Cl		
Gypidula coppingeri (Etheridge)			MS	
Gypidula globosa (Nettelroth)			N	
Gypidula knotti (Nettelroth)			N	
Gypidula nuclea (Hall and Whitfield)		Cl		
Gypidula roemeri Hall and Clarke			N	
Gypidula uniplicata (Nettelroth)			N	
Hebertella daytonensis (Foerste)		Cl		
Hebertella fausta (Foerste)		Cl		
Hindella prinstana (Billings)		A		
Hindella umbonata (Billings)		A		

Digitized by Google

TABLE V.—*Silurian Brachiopoda*—Continued.

Species.	Eosilurian.	Mesosilurian.		Neosilurian.
	Medina.	Anticosti, Clinton.	Guelph, Arisaig, Niagara.	Tentaculite, Waterlime.
Homœospira apriniformis Hall			N	
Homœospira evax Hall			N	
Homœospira sobrina (Beecher and Clarke)			N	
Hyattella congesta (Conrad)		Cl		
Hyatella junia (Billings)		A		
†* Leptæna rhomboidalis (Wilckens)		Cl	N	
Lingula acutirostra Hall		Cl		
Lingula bicarinata Ringueberg			N	
Lingula clintoni Vanuxem		Cl		
Lingula cuneata Conrad	×			
Lingula gibbosa Hall			N	
Lingula ingens Spencer			N	
Lingula insularis Billings		A		
Lingula lamellata Hall			N	
Lingula linguata Hall and Clarke		Cl		
Lingula oblata Hall		Cl		
Lingula subelliptica d'Orbigny		Cl		
Lingula tæniola Hall and Clarke		Cl		
Lingulops granti Hall and Clarke			N	
Meristina maria Hall			N	
Meristina rectirostra Hall			N	
Meristina trisinuata (McChesney)			N	
Mimulus waldronensis (Miller and Dyer)			N	
Monomorella egani Hall and Clarke			N	
Monomorella greenii Hall and Clarke			N	
Monomorella kingi Hall and Clarke			N	
Monomorella newberryi Hall and Whitfield			N	
Monomorella orbicularis Billings			Gu	
Monomorella ortoni Hall and Clarke			N	
Monomorella ovata Whiteaves			Gu	
Monomorella ovata lata Whiteaves			Gu	
Monomorella prisca Billings			Gu	
* Nucleospira elegans Hall			N	
Nucleospira pisiformis Hall			N	
Nucleospira rotundata Whitfield				W
Orbiculoidea numulus Hall and Clarke				W
Orbiculoidea parmulata Hall	×			
Orbiculoidea subplana (Hall)			Ar	
Orbiculoidea vanuxemi (Hall)			Ar	W
Orthis benedicti Miller			N	
Orthis davidsoni de Verneuil		A	N	
Orthis (?) fissiplica Roemer			N	
Orthis flabellites (Hall) Foerste		Cl	N	
Orthis flabellites spania Hall and Clarke			N	
Orthis (?) glypta Hall and Clarke			N	
Orthis (?) missouriensis Shumard			N ?	
Orthis (?) nisis Hall and Whitfield			N	
Orthis (?) punctostriata Hall			N	
Orthis (?) rugiplicata Hall and Whitfield			N	
Orthis (?) ruida Billings		A		
Orthis (?) subnodosa Hall			N	
Orthis (?) tennidens Hall		Cl		

Digitized by Google

TABLE V.—*Silurian Brachiopoda*—Continued.

Species.	Eosilurian.	Mesosilurian.		Neosilurian.
	Medina.	Anticosti, Clinton.	Guelph, Arisaig, Niagara.	Tentaculite, Waterlime.
Orthis (?) trinucleus Hall		Cl		
Orthostrophia (?) fasciata Hall			N	
Orthothetes hydraulicum (Whitfield)				W
Orthothetes interstriata (Hall)				Te
*Orthothetes subplana (Conrad)			N	
Orthothetes tenuis Hall			N	
Orthotropia dolomitica Hall and Clarke			N	
Parastrophia greenii Hall and Clarke			N	
Parastrophia latiplicata Hall and Clarke			N	
Parastrophia multiplicata Hall and Clarke			N	
Parastrophia ops (Billings)		A		
Parastrophia reversa (Billings)		A		
Pentamerella (?) compressa Ringueberg			N	
Pentamerus oblongus Sowerby		Cl	N	
Pentamerus oblongus cylindricus (Hall and Whitfield)			N	
Pentamerus oblongus maquoketa Hall and Clarke			N	
Pentamerus oblongus subrectus Hall and Clarke			N	
Pentamerus ovalis Hall		Cl		
Pentamerus pesovis Whitfield				W
Pholidops ovalis Hall			N	
Pholidops squamiformis Hall			N	
†Platystrophia biforata (Schlotheim)		Cl	N	
Plectambonites glabra Shaler		A		
Plectambonites producta Hall and Clarke			N	
†Plectambonites sericea (Sowerby)		Cl		
Plectambonites transversalis (Wahlenberg)		Cl	N	
Plectambonites transversalis alabamensis Foerste		Cl		
Plectambonites transversalis prolongata Foerste		Cl		
†Rafinesquina ceres (Billings)		A		
Rafinesquina (?) obscura (Hall and Clarke)		Cl		
Reticularia bicostata (Vanuxem)			N	
Reticularia bicostata petila (Hall)			N	
Rhinobolus davidsoni Hall and Clarke			N	
Rhinobolus galtensis (Billings)			Gu	
Rhipidomella circula Hall		Cl		
Rhipidomella hybrida (Sowerby)			N	
Rhipidomella media (Shaler)		A		
Rhipidomella rhynchonelliformis (Shaler)		A		
Rhipidomella subcircula (Simpson)		Cl		
Rhipidomella ubera (Billings)		A		
Rhynchonella (?) argentea Billings		A		
Rhynchonella (?) bellaforma Nettelroth			N	
Rhynchonella (?) bidens Hall		Cl		
Rhynchonella (?) bidentata (Hisinger)			N	
Rhynchonella (?) colletti Miller			N	
Rhynchonella (?) decemplicata Sowerby		Cl		
Rhynchonella (?) emacerata Hall		Cl	Ar	
Rhynchonella (?) eva Billings		A		
Rhynchonella (?) hydraulica Whitfield				W
†Rhynchonella (?) janea Billings		A		
Rhynchonella (?) lævis Simpson		Cl		
Rhynchonella (?) lamellata Hall				Te

Digitized by Google

TABLE V.—*Silurian Brachiopoda*—Continued.

Species.	Eosilurian.	Mesosilurian.		Neosilurian.
	Medina.	Anticosti, Clinton.	Guelph, Arisaig, Niagara.	Tentaculite, Waterlime.
Rhynchonella (?) nucula (Sowerby)			N	
Rhynchonella (?) nutrix Billings		A		
Rhynchonella (?) pisa Hall and Whitfield			N	
Rhynchonella (?) plicata Hall	×			
Rhynchonella (?) plicatella (Linnæus)			N	
Rhynchonella (?) pyrrha Billings		A		
Rhynchonella (?) robusta Hall		Cl		
Rhynchonella (?) rugæcosta Nettelroth			N	
Rhynchonella (?) tennesseensis Roemer			N	
Rhynchonella (?) vicina Billings		A		
Rhynchospira (?) acadiæ (Hall)			Ar	
Rhynchospira (?) helena (Nettelroth)			N	
Rhynchospira (?) sinuata Hall			Ar	
Rhynchotreta cuneata americana Hall			N	
Scenidium pyramidale Hall			N	
Schizophoria senecta Hall and Clarke		Cl		
Schizotreta tenuilamellata Hall			N	
Spirifer asperatus Ringueberg			N	
Spirifer crispatus Hall and Clarke			N	
Spirifer crispus (Hisinger)			N	Te
Spirifer crispus simplex Hall			N	
Spirifer dubius Nettelroth			N?	
Spirifer eudorus Hall			N	
Spirifer foggi Nettelroth			N	
Spirifer gibbosus Hall			N	
Spirifer niagarensis (Conrad)			N	
Spirifer niagarensis oligoptychus Roemer			N	
Spirifer nobilis Barrande			N	
Spirifer radiatus Sowerby		Cl	N	
Spirifer rostellum Hall and Whitfield			N	
Spirifer similior Winchell and Marcy			N	
Spirifer subsulcatus Hall			Ar	
Spirifer vanuxemi Hall				Te
Streptis grayi Davidson			N	
Stricklandinia anticostiensis Billings		A		
Stricklandinia billingsana Dawson			Ar	
Stricklandinia brevis Billings		A		
Stricklandinia canadensis Billings		Cl		
Stricklandinia castellana White			N	
Stricklandinia chapmani Hall and Clarke			N	
Stricklandinia davidsoni Billings		A		
Stricklandinia deformis Meek and Worthen			N	
Stricklandinia gaspensis Billings			N	
Stricklandinia lens (Sowerby)			N?	
Stricklandinia lirata Billings		A		
Stricklandinia (?) louisvillensis Nettelroth			N	
Stricklandinia melissa Billings		A		
Stricklandinia multilirata Whitfield			Gu	
Stricklandinia salteri Billings		A		
Stricklandinia triplesiana Foerste		Cl		
Stropheodonta acanthoptera (Whiteaves)			N?	
Stropheodonta corrugata Conrad		Cl		

Digitized by Google

TABLE V.—*Silurian Brachiopoda*—Continued.

Species.	Eosilurian.	Mesosilurian.		Neosilurian.
	Medina.	Anticosti, Clinton.	Guelph, Arissig, Niagara.	Tentaculite, Waterlime.
Strophеodonta corrugata pluristriata Foerste		Cl		
Strophеodonta (?) geniculata (Shaler)		A		
Strophеodonta (?) gilpeni (Dawson)			Ar	
Strophеodonta leda (Billings)		A		
Strophеodonta macra (Winchell and Marcy)			N	
Strophеodonta nearpassi Barrett				To
Strophеodonta prisca Hall		Cl		
Strophеodonta profunda Hall		Cl	N	
Strophеodonta textilis Hall				To
Strophеodonta (?) ventricosa (Shaler)		A		
Strophomena (?) alterniradiata Shaler		A		
Strophomena (?) antiquata Sowerby		A		
Strophomena (?) arcuata Shaler		A		
Strophomena (?) bipartita Hall				To
Strophomena (?) doneti Salter			MS	
Strophomena (?) eliptica Conrad			N	
Strophomena (?) julia Billings		A		
Strophomena (?) modesta Conrad		Cl?		
Strophomena (?) orthididea Hall		Cl		
Strophomena philomela Billings		A		
Strophomena (?) reticulata Shaler			N	
Strophomena (?) semiovalis Shaler		A		
Strophomena (?) siluriana Davidson			N	
Strophonella costatula Hall and Clarke			N	
Strophonella (?) patenta Hall		Cl		
Strophonella semiplicata Hall			N	
Strophonella striata Hall			N	
Trematospira camura Hall			N	
Trimerella acuminata Billings			Gu	
Trimerella billingsi Dall			Gu	
Trimerella dalli Davidson and King			Gu	
Trimerella grandis Billings			Gu	
Trimerella ohioensis Meek			N	
Triplecia niagarensis Hall and Clarke			N	
Triplecia ortoni Meek		Cl		
Uncinulus stricklandi (Sowerby)			N	
Whitfieldella billingsana (Meek and Worthen)			N	
Whitfieldella cylindrica Hall		Cl	N	
Whitfieldella hyale (Billings)			Gu	
Whitfieldella intermedia (Hall)		Cl	N	
Whitfieldella (?) julia (Billings)		A		
Whitfieldella (?) naviformis (Hall)		Cl	N	
Whitfieldell nitida Hall			N	
Whitfieldella nitida oblata Hall			N	
Whitfieldella (?) nucleolata (Hall)				To
Whitfieldella oblata (Hall)	×			
Whitfieldella sulcata (Vanuxem)				W
Wilsonia kokomoensis (Miller)				W
* Wilsonia saffordi Hall			N	
Wilsonia saffordi depressa Nettelroth			N	
Wilsonia wilsoni (Sowerby)			N	
Zygospira (?) mica (Billings)		A		

Digitized by Google

TABLE V.—*Silurian Brachiopoda*—Continued.

Species.	Eosilurian.	Mesosilurian.		Neosilurian.
	Medina.	Anticosti, Clinton.	Guelph, Arisaig, Niagara.	Tentaculite, Waterlime.
Zygospira (?) minima Hall	.....	.....	N	.....
Zygospira (?) paupera Billings	.....	A	.....	.....
Number of Silurian species, 311.				
Number of species in each division	4	116	195	17
Number of species common to the Medina and the other divisions	0	0	0	0
Number of species common to the Clinton and the other divisions	0	.....	19	0
Number of species common to the Niagara and the other divisions	0	19	.....	2
Number of species common to the Neosilurian and the other divisions	0	0	2	.....
Species common to the Silurian and Devonian systems, 5.				
Number of species passing from each division into the Devonian	0	2	5	0

Digitized by Google

TABLE VI.—*Devonian Brachiopoda.*

[C = Chemung; Co = Corniferous; ED = Eodevonian; G = Genesee; H = Hamilton; Hu = Huron; I = Ithaca; M = Marcellus; MD = Mesodevonian; ND = Neodevonian; P = Portage; S = Schoharie; Tu = Tully. Species preceded by an asterisk (*) are found in the Carboniferous also; by an obelisk (†), in the Silurian.]

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Amboccelia fimbriata Claypole					P	
Amboccelia gregaria Hall						C
Amboccelia præumbona Hall				H		
Amboccelia spinosa Hall and Clarke				H		
Amboccelia umbonata (Conrad)			Co	M, H	G	I, C
Amphigenia curta (Meek and Worthen)		×				
Amphigenia elongata (Vanuxem)		×	Co			
Amphigenia elongata subtrigonalis Hall			Co			
Amphigenia elongata undulata Hall			Co			
Anastrophia verneuili (Hall)	×					
Anoplia nucleata Hall		×	Co			
Anoplotheca acutiplicata (Conrad)		×	Co			
Anoplotheca camilla (Hall)		×	Co	M		
Anoplotheca concava (Hall)	×					
Anoplotheca dichotoma (Hall)		×				
Anoplotheca fimbriata (Hall)		×				
Anoplotheca flabellites (Conrad)		×	Co			
Anoplotheca infrequens (Walcott)	ED				ND	
Athyris angelica Hall						C
Athyris angelica occidentalis Whiteaves				H		
Athyris brittai Miller				MD		
Athyris cora Hall				H		C?
Athyris fultonensis (Swallow)			Co	H		
Athyris minutissima Webster						C
Athyris (?) ottervillensis Miller				MD		
Athyris parvula Whiteaves				H		
Athyris polita Hall						C
Athyris spiriferoides (Eaton)			Co	H		
Atrypa desquamata Sowerby				H		
Atrypa ellipsoidea Nettelroth			Co			
Atrypa hystrix Hall						C
Atrypa hystrix elongata Webster						C
Atrypa hystrix occidentalis Hall				MD		
Atrypa hystrix planosulcata Webster						C
Atrypa missouriensis Miller				MD		
Atrypa pseudomarginalis Hall			S			
†Atrypa reticularis (Linnæus)	×		Co, S	H, Tu		I, C
Atrypa reticularis impressa Hall			S			
Atrypa reticularis nuntia Hall and Whitfield				H		
Atrypa reticularis ventricosa Hall and Whitfield				H		
Atrypa spinosa Hall			Co	H		C
Atrypina imbricata Hall	×					
Barroisella subspatulata (Meek and Worthen)					G	
Beachia suessana Hall		×				
Bilobites varicus (Conrad)	×					
Camarophoria rhomboidalis Hall and Clarke			Co			
Camarospira eucharis Hall			Co			
Camarotœchia barrandi Hall		×				

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Camarotœchia billingsi Hall	.....	.....	Co	.....	.....	.....
Camarotœchia carica Hall	.....	.....	.....	H	.....	.....
Camarotœchia carolina Hall	.....	.....	Co	.....	.....	.....
Camarotœchia congregata (Conrad)	.....	.....	.....	H	.....	.....
*Camarotœchia contracta Hall	.....	.....	.....	.....	P	C
Camarotœchia contracta saxatilis Hall	.....	.....	.....	H	.....	.....
Camarotœchia dotis Hall	.....	.....	.....	M, H	.....	.....
Camarotœchia duplicata Hall	.....	.....	.....	.....	.....	C
Camarotœchia endlichi (Meek). ? Devonian.						
Camarotœchia eximia Hall	.....	.....	.....	.....	P	I, C
Camarotœchia horsfordi Hall	.....	.....	.....	M, H	.....	.....
Camarotœchia orbicularis Hall	.....	.....	.....	.....	.....	C
Camarotœchia pleiopleura (Conrad)	.....	×	.....	.....	.....	.....
Camarotœchia prolifica Hall	.....	.....	.....	M, H	.....	.....
*Camarotœchia sappho Hall	.....	.....	.....	M, H	.....	C
Camarotœchia speciosa Hall	.....	×	.....	.....	.....	.....
Camarotœchia stephani Hall	.....	.....	.....	.....	P	C
Camarotœchia tethys (Billings)	.....	.....	Co	.....	.....	.....
Camarotœchia ventricosa Hall	×	.....	.....	.....	.....	.....
Centronella alveata Hall	.....	.....	Co	.....	.....	.....
Centronella glansfagea Hall	.....	×	Co	.....	.....	.....
Centronella glaucia Hall	.....	.....	.....	H	.....	.....
Centronella impressa Hall	.....	.....	.....	H	.....	.....
Centronella (?) navicella (Hall)	.....	.....	.....	.....	.....	C
Centronella ovata Hall	.....	.....	Co	.....	.....	.....
Centronella tumida Billings	.....	×	Co	.....	.....	.....
Charionella scitula Hall	.....	.....	Co	.....	.....	.....
Chonetes acutiradiata Hall	.....	.....	Co	.....	.....	.....
Chonetes antiope Billings	.....	×?	.....	.....	.....	.....
Chonetes arcuata Hall	.....	.....	Co	.....	.....	.....
Chonetes canadensis Billings	.....	×?	.....	.....	.....	.....
Chonetes coronata (Conrad)	.....	.....	.....	H	.....	.....
Chonetes emmetensis A. Winchell	.....	.....	.....	H	.....	.....
Chonetes filistriata Walcott	.....	ED	.....	.....	.....	.....
Chonetes hemispherica Hall	.....	.....	Co	.....	.....	.....
Chonetes koninckiana Norwood and Pratten	.....	.....	.....	MD	.....	.....
Chonetes lepida Hall	.....	.....	.....	M, H	G, P	I, C
Chonetes lineata (Conrad)	.....	.....	Co	M	.....	.....
*Chonetes logani aurora Hall	.....	.....	.....	Tu	.....	.....
Chonetes manitobensis Whiteaves	.....	.....	.....	.....	.....	ND
Chonetes melonica Billings	.....	×	.....	.....	.....	.....
Chonetes mucronata Hall	.....	×	Co	M, H	.....	.....
Chonetes punctata Simpson	×	.....	.....	.....	.....	.....
Chonetes pusilla Hall	.....	.....	.....	H	.....	.....
Chonetes scitula Hall	.....	.....	.....	M, H	P	I, C
*Chonetes setigera (Hall)	.....	.....	.....	M, H	G	C
Chonetes subquadrata Nettelroth	.....	.....	.....	H	.....	.....
Chonetes vicina (Castelnau)	.....	.....	.....	H	.....	.....
Chonetes yandellana Hall	.....	.....	Co	.....	.....	.....
Chonostrophia complanata Hall	.....	×	.....	.....	.....	.....
Chonostrophia dawsoni (Billings)	.....	×?	.....	.....	.....	.....

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Cornif-erous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Chonostrophia helderbergiæ Hall	×					
Chonostrophia reversa (Whitfield)			Co			
Christiania subquadrata Hall	×					
Conchidium knighti Nettelroth			Co?			
Conchidium (?) salienense (Swallow)				H?		
Cranæna iowensis (Calvin)				MD		
Cranæna romingeri Hall				H		
Crania agaricina Hall and Clarke	×					
Crania aurora Hall			S			
Crania bella Billings		× ?				
Crania centralis Hall					P	
Crania crenistriata Hall			Co	H		
Crania famelica Hall and Whitfield				H		
Crania favincola Hall and Clarke				MD		
Crania granosa Hall and Clarke				H		
Crania greenii Miller			Co			
Crania leoni Hall					P	C
Crania pulchella Hall and Clarke	×					
Crania sheldoni White				H		
Craniella hamiltoniæ Hall				M, H		
Cryptonella (?) circula Walcott. Devonian.						
* Cryptonella (?) eudora Hall						I, C
Cryptonella (?) eximia Hall	×					
Cryptonella iphis Hall			Co			
Cryptonella lens Hall			Co			
Cryptonella ovalis Miller				H		
Cryptonella pinonensis Walcott						ND
Cryptonella planirostra Hall				M, H		
Cryptonella rectirostra Hall				H		
Cyclorhina nobilis Hall				H		
Cyrtia cyrtinaformis Hall and Whitfield						C
Cyrtia norwoodi (Meek)				MD		
Cyrtina affinis Billings		×				
Cyrtina billingsi Meek				H		
Cyrtina biplicata Hall			Co			
Cyrtina crassa Hall			Co			
Cyrtina curvilineata White				H		
Cyrtina dalmani Hall	×					
Cyrtina davidsoni Walcott				MD		ND
Cyrtina hamiltonensis Hall			Co	H	P	I
Cyrtina hamiltonensis recta Hall				H		C
Cyrtina missouriensis (Swallow)				H		
Cyrtina (?) occidentalis (Swallow)				H		
Cyrtina rostrata (Hall)		×	Co			
Cyrtina tiquetra (Hall)				H		
Cyrtina umbonata (Hall)				H		
Cyrtina umbonata alpenensis Hall and Clarke				H		
Dalmanella concinna (Hall)	×					
Dalmanella devonica (Walcott)		ED				
Dalmanella infera (Calvin)						C
Dalmanella lenticularis (Vanuxem)			Co			

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Cornif-erous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Dalmanella lepida Hall				H		
Dalmanella perelegans Hall	×	×				
Dalmanella planoconvexa Hall	×	×				
Dalmanella quadrans Hall	×					
Dalmanella subcarinata Hall	×					
Dalmanella superstes Hall and Clarke						C
Dalmanella tenuilineata Hall						C
Delthyris consobrina (d'Orbigny)				H		
Delthyris mesacostalis Hall						I, C
Delthyris perlamellosa (Hall)	×					
Delthyris raricosta Conrad			Co			
Delthyris sculptilis Hall				H		
Dielasma calvini Hall and Whitfield						C
Dignomia alveata Hall				H		
Eatonia coulteri Miller and Gurley		×				
Eatonia eminens Hall	×					
Eatonia medialis (Vanuxem)	×	×				
Eatonia peculiaris (Conrad)	×	×				
Eatonia pumila Hall		×				
Eatonia singularis (Vanuxem)	×					
Eatonia sinuata Hall		×				
Eatonia (?) variabilis Whiteaves				H		
Eatonia whitfieldi Hall		×				
Eunella harmonia Hall			Co			
Eunella lincklæni Hall				M, H		
Eunella simulator Hall				H		
Eunella sullivanti Hall			Co			
Glossina leana (Hall)				H		
Glossina spatiosa (Hall)	×					
Glossina triangulata (Nettelroth)				H		
Gypidula comis (Owen)				MD		
Gypidula galeata (Dalman)	×					
Gypidula læviuscula Hall				MD		
Gypidula lotis (Walcott)						ND
Gypidula munda Calvin				MD		
Gypidula pseudogaleata (Hall)	×					
Gypidula romingeri Hall and Clarke				H		
Gypidula subglobosa (Meek and Worthen)				H		
Hipparionyx proximus Vanuxem		×				
Hypothyris castanea (Meek)				MD		
Hypothyris cuboides (Sowerby)				Tu		
Hypothyris emmonsi (Hall and Whitfield)				MD		
Leiorhynchus dubium Hall				M		
Leiorhynchus globuliforme (Vanuxem)						C
Leiorhynchus hecate Clarke					G	
Leiorhynchus iris Hall						C
Leiorhynchus kelloggi Hall				H		
Leiorhynchus laura Billings				M, H		
Leiorhynchus lesleyi Hall and Clarke						ND
Leiorhynchus limitare (Vanuxem)				M		
Leiorhynchus mesacostale Hall					P	I, C

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie. Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Leiorhynchus mysia Hall				M		
Leiorhynchus nevadense Walcott				MD		
Leiorhynchus quadricostatum (Vanuxem)				M	G	
Leiorhynchus robustum Hall and Clarke						C
Leiorhynchus sesquiplicatum A. Winchell				H		
Leiorhynchus sinuatum Hall						C
†*Leptæna rhomboidalis (Wilckens)	×	×	Co	H		C
Leptæna rhomboidalis ventricosa Hall		×				
Leptænisca adnascens Hall and Clarke	×					
Leptænisca concava Hall	×					
Leptænisca tangens Hall	×					
Lindstrœmella aspidium Hall				H		
Lingula albapinensis Walcott						ND
Lingula artemis Billings		× ?				
Lingula centrilineata Hall	×					
Lingula ceryx Hall			S			
Lingula complanata Williams				H		I
Lingula compta Hall and Clarke				H		
Lingula concentrica Conrad			Co ?			
*Lingula cuyahoga Hall						C
Lingula delia Hall				H		
Lingula densa Hall				H		
Lingula desiderata Hall			Co			
Lingula ligea Hall				H	P	
Lingula ligea nevadensis Walcott		ED				
Lingula lonensis Walcott		ED				
Lingula lucretia Billings		× ?				
Lingula maida Hall				H		
Lingula manni Hall			Co			
Lingula minuta Meek				H		
Lingula nuda Hall				H		
Lingula perlata Hall	×					
Lingula punctata Hall				H		I
Lingula rectilatera Hall	×					
Lingula scutella Hall and Clarke						C
Lingula spathata Hall	×					
Lingula spatulata Vanuxem				H	G, P	I
Lingula thedfordensis Whiteaves				H		
Lingula triquetra Clarke					P	
Lingula whitii Walcott		ED				
Lingulella (?) paliformis Hall				H		
Lingulodiscina exilis (Hall)				M		
Lissopleura æquivalvis (Hall)	×					
Martinia athyroides A. Winchell				H		
Martinia glanceraai (White)				H		
Martinia (?) insolita A. Winchell					Hu	
Martinia maia (Billings)			Co			
Martinia meristoides Meek				H		
Martinia sublineata Meek				H		
Martinia subumbona (Hall)				M, H	P	
Megalanteris condoni (McChesney)		×				

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung. Ithaca.
Megalanteris ovalis Hall		×				
Merista elongata Hall	×					
Merista tennesseensis Hall	×					
Merista typa Hall	×					
Meristella arcuata Hall	×					
Meristella barrisi Hall				M, H		
Meristella bella (Hall)	×					
Meristella (?) blancha (Billings)	×					
Meristella clusia (Billings)			Co			
Meristella doris Hall			Co			
Meristella haskinsi Hall				H		
Meristella (?) houghtoni (A. Winchell)					Hu	
Meristella lævis (Vanuxem)	×					
Meristella lata Hall		×				
Meristella lens (A. Winchell)				H		
Meristella lenta Hall		×				
Meristella meeki Hall	×					
Meristella meta Hall				H		
Meristella nasuta (Conrad)			Co			
Meristella princeps Hall	×					
Meristella rostrata Hall				H		
Meristella subquadrata (Hall)	×					
Meristella walcotti Hall and Clarke		×				
Metaplasia disparilis (Hall)			Co			
Metaplasia pyxidata (Hall)		×				
Newberria claypoli Hall				H		
Newberria johannis Hall				MD		
Newberria lævis (Meek)				H		
Newberria missouriensis Hall				H		
Nucleospira concentrica Hall	×					
Nucleospira concinna Hall			Co	H		
Nucleospira elegans Hall	×					
Nucleospira ventricosa Hall	×					
Orbiculoidea alleghania (Hall)						C
Orbiculoidea ampla Hall		×				
Orbiculoidea conradi (Hall)	×					
Orbiculoidea discus Hall	×					
Orbiculoidea doria (Hall)				H		
Orbiculoidea elmira (Hall)						C
Orbiculoidea humilis (Hall)				M, H		
Orbiculoidea jervensis (Barrett)		×				
Orbiculoidea lodensis (Vanuxem)					G	
Orbiculoidea lodensis media Hall				M, H		C
Orbiculoidea marginalis (Whitfield)				H		
Orbiculoidea minuta Hall				M, H		
Orbiculoidea neglecta (Hall)						C
Orbiculoidea randalli Hall				H		
Orbiculoidea seneca (Hall)				H		
Orbiculoidea tullia (Hall)				Tu		
Oriskania navicella Hall and Clarke		×				
Orthis (?) eryna Hall			Co			

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Orthis (?) tenuistriata Hall					P	
Orthostrophia strophomenoides Hall	×					
Orthothetes anomala (A. Winchell)				H		
Orthothetes bellulus Clarke				M		
Orthothetes chemungensis (Conrad)						C
Orthothetes chemungensis arctostriata Hall				M, H	P	
Orthothetes chemungensis perversus Hall			Co	H		
Orthothetes deformis Hall	×					
Orthothetes deformis sinuata Hall and Clarke	×					
Orthothetes flabellum (Whitfield)			Co			
Orthothetes pandora (Billings)			Co	M		
Orthothetes prava Hall						ND?
?Orthothetes subplana (Conrad)	×					
Orthothetes woolworthana Hall	×					
Parazyga deweyi Hall	×					
Parazyga hirsuta Hall			Co	H		
Pentagonia uniaulcata (Conrad)		×	Co	H		
Pentamerella arata (Conrad)			Co			
Pentamerella borealis (Meek)				H		
Pentamerella dubia Hall				H?		
Pentamerella intralineata (A. Winchell)				H		
Pentamerella micula Hall				H?		
Pentamerella obsolescens Hall				H?		
Pentamerella pavillionensis Hall				H		
Pentamerella thusnelda Nettelroth			Co			
Pholidops arenaria Hall		×				
Pholidops areolata Hall			S			
Pholidops bellula Walcott		ED				
Pholidops calceola Hall and Clarke			Co			
Pholidops greenii Miller and Gurley				H		
Pholidops hamiltoniæ Hall				H		
Pholidops lepis Hall and Clarke			Co			
Pholidops oblata Hall				H		
Pholidops ovata Hall	×					
Pholidops patina Hall and Clarke			Co			
Pholidops quadrangularis Walcott		ED				
Pholidops terminalis Hall		×				
Pholidostrophia iowensis (Owen)			Co	H		
Plectorthis (?) aurelia (Billings)		×				
Productella arctirostrata Hall						C
Productella bialveata Hall						C
Productella boydi Hall						C
Productella costatula Hall						C
Productella costatula strigata Hall						C
Productella dumosa Hall				H		
Productella eriensis Nicholson			Co			
Productella exanthemata Hall			Co	H		
Productella hallana Walcott						ND
Productella hirsuta Hall						C
Productella hirsuta rectispina Hall						C
Productella hirsutiforme (Walcott)						ND

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Productella lachrymosa (Conrad)						C
Productella lachrymosa lima (Conrad)						C
*Productella lachrymosa stigmata Hall						C
Productella marquessi Rowley				H		
Productella murchisoniana De Koninck				H		
Productella navicella Hall			Co	H		
Productella onusta Hall						C
Productella papulata Hall				H		
Productella productoides (Murchison)				H		
Productella rarispina Hall						C
Productella semiglobosa Nettelroth			Co			
*Productella speciosa Hall					P	I, C
Productella spinulicosta Hall			Co	M, H		
Productella striatula Hall						C
Productella subalata Hall				MD		
Productella tullia Hall				H		
Pugnax pugnus Martin					P	I
Pugnax pugnus altus (Calvin)						ND
Rensselæria æquiradiata (Conrad)	×					
Rensselæria cayuga Hall and Clarke		×				
Rensselæria cumberlandiæ Hall		×				
Rensselæria elliptica Hall	×					
Rensselæria intermedia Hall		×				
Rensselæria marylandica Hall		×				
Rensselæria mutabilis Hall	×					
Rensselæria ovoides (Eaton)		×				
Rensselæria ovalum Hall and Clarke		×				
Reticularia canandaiguæ (Hall and Clarke)				H		
Reticularia fimbriata (Conrad)		×	Co	M, H		I
Reticularia franklini (Meek)				H		
Reticularia knappiana (Nettelroth)			Co			
Reticularia lævis (Hall)					P	I
Reticularia modesta (Hall)	×	×				
Reticularia nevadensis (Walcott)						ND
Reticularia (?) nympha (Billings)	×					
Reticularia prœmatura (Hall)						C
Reticularia subundifera (Meek and Worthen)				H		
Retzia (?) polypleura A. Winchell					P	
Retzia (?) subglobosa Hall			S			
Rhipidomella alsa Hall			S			
Rhipidomella assimilis Hall	×					
Rhipidomella cleobis Hall			Co			
Rhipidomella cumberlandiæ Hall		×				
Rhipidomella (?) cuneata (Owen)				H		
Rhipidomella cyclas Hall				M, H		
Rhipidomella discus Hall	×					
Rhipidomella eminens Hall	×					
Rhipidomella goodwini (Nettelroth)				H		
Rhipidomella idonea Hall				H		
Rhipidomella leucosia Hall				H		
Rhipidomella livia (Billings)			Co			
Rhipidomella lucia Billings		×				

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Rhipidomella (?) mitis (Hall)			S			
Rhipidomella musculosa Hall		×				
Rhipidomella oblata Hall	×					
Rhipidomella oblata emarginata Hall	×					
Rhipidomella peloris Hall			S			
Rhipidomella penelope Hall				H		
Rhipidomella pennsylvanica (Simpson)						C
Rhipidomella semele Hall			Co			
Rhipidomella solitaria Hall				H		
Rhipidomella suborbicularis Hall				H		
*Rhipidomella thiemii (White)						C
Rhipidomella tubulostriata Hall	×					
Rhipidomella vanuxemi Hall			Co	M, H		
Rhynchonella acutiplicata Hall	×					
Rhynchonella alleganis Williams						C
Rhynchonella altiplicata Hall	×					
Rhynchonella ambigua Calvin				MD		
Rhynchonella aspasia Billings	×					
Rhynchonella bialveata Hall	×					
Rhynchonella dryope Billings		×				
Rhynchonella eminens Hall	×					
Rhynchonella excellens Billings		×				
Rhynchonella fitchana Hall		×				
Rhynchonella gainesi Nettelroth				H		
Rhynchonella huronensis A. Winchell					Hu	
Rhynchonella huronensis precipua A. Winchell					Hu	
Rhynchonella inæquiplicata Hall			Co			
Rhynchonella inutilis Hall	×					
Rhynchonella louisvillensis Nettelroth			Co			
Rhynchonella mainensis Billings	×					
Rhynchonella medea Billings			Co			
Rhynchonella multistriata Hall		×				
Rhynchonella oblata Hall		×				
Rhynchonella occidens Walcott		ED				
Rhynchonella planoconvexa Hall	×					
Rhynchonella principalis Hall		×				
Rhynchonella ramsayi Hall		×				
Rhynchonella raricosta Whitfield			Co			
Rhynchonella royana Hall			Co			
Rhynchonella rudis Hall	×					
Rhynchonella semiplicata (Conrad)	×					
Rhynchonella septata Hall		×				
Rhynchonella subacuminata Webster						C
Rhynchonella sulcoplicata Hall	×					
Rhynchonella tenuistriata Nettelroth			Co			
Rhynchonella transversa Hall	×					
Rhynchonella warrenensis Swallow		ED				
Rhynchospira electra Billings	×					
Rhynchospira (?) eugenia Billings			Co			
Rhynchospira formosa Hall	×					
Rhynchospira globosa Hall	×					

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Rhynchospira rectirostra Hall		×				
Rhynchotrema formosa (Hall)	×					
Rœmerella grandis Vanuxem				H		
Scenidium insignis Hall	×					
Schizobolus concentricus (Vanuxem)					G	
Schizocrania (?) helderbergia Hall	×					
Schizocrania superincreta Barrett	×					
Schizophoria carinata Hall						C
Schizophoria macfarlani (Meek)				MD		ND
Schizophoria manitobensis Whiteaves						ND
Schizophoria multistriata Hall	×					
Schizophoria (?) peduncularis Hall	×					
Schizophoria propinqua Hall			Co			
Schizophoria striatula (Schlotheim)				MD		ND
Schizophoria tioga Hall					P	C
Schizophoria tulliensis (Vanuxem)				Tu		
Selenella gracilis Hall and Clarke			Co			
Seminula (?) rogersi Hall and Clarke			Co			
Spirifer acanthopterus (Conrad)				H		
Spirifer acuminatus (Conrad)			Co	H		
Spirifer alæformis de Verneuil			Co			
Spirifer aldrichi Etheridge. Devonian.						
Spirifer amarus Swallow				H		
Spirifer angustus Hall				H	P	
Spirifer annæ Swallow				H		
Spirifer arcticus Haughton. Devonian.						
Spirifer arctisegmentus Hall			Co			
Spirifer arenosus Conrad		×	Co			
Spirifer asper Hall				H		
Spirifer audaculus (Conrad)				M, H		
Spirifer audaculus macronotus Hall				H		
Spirifer belphegor Clarke					G	
Spirifer bidorsalis A. Winchell				H		
Spirifer billingsanus Miller		×				
Spirifer bimesialis Hall						ND
Spirifer byrnesi Nettelroth				H		
Spirifer concinnus Hall	×					
Spirifer consors A. Winchell				H		
Spirifer corticosus Hall				H		
Spirifer (?) costalis Castelnau			Co?			
Spirifer cumberlandiæ Hall		×				
Spirifer cyclopterus Hall	×	×				
Spirifer davisi Nettelroth				H		
Spirifer diajunctus Sowerby						C
Spirifer diajunctus occidentalis Whiteaves						ND
Spirifer diajunctus sulcifer Hall and Clarke						C
Spirifer divaricatus Hall			Co	H		
Spirifer duodenarius Hall			Co			
Spirifer dupliplicatus (Conrad)				H		
Spirifer engelmanni Meek				MD		
Spirifer euruteines Owen				H		

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Spirifer filicostus A. Winchell				H		
Spirifer formosus Hall				H		
Spirifer fornaculus Hall				H		
Spirifer fornax Hall				H		
Spirifer gaspensis Billings		×				
Spirifer granulosus (Conrad)				H		
Spirifer gregarius Hall			Co			
Spirifer grieri Hall			Co			
Spirifer hemicyclus Meek and Worthen		×				
Spirifer hobbsi Nettelroth				H		
Spirifer hungerfordi Hall						C
Spirifer huronensis A. Winchell					P	
Spirifer intermedius Hall		×				
Spirifer inutilis Hall						ND
Spirifer iowensis Owen				MD		
Spirifer kennicotti Meek				MD		
Spirifer macbridii Calvin						ND
Spirifer macconathii Nettelroth				H		
Spirifer macrus Hall			Co			
Spirifer macropleurus (Conrad)	×					
Spirifer macrothyris Hall			Co			
Spirifer manni Hall			Co			
Spirifer marcyi Hall				H		
Spirifer mesastrialis Hall					P	I, C
Spirifer multicostatus Castelnau			Co?			
Spirifer murchisoni Castelnau		×				
Spirifer nictavensis Dawson		×				
Spirifer octocostatus Hall	×					
Spirifer orestes Hall and Whitfield						C
Spirifer paradoxus (Schlotheim)			Co			
Spirifer pennatus (Atwater)				M, H		I
Spirifer pennatus posterus Hall and Clarke						C
Spirifer pennatus tulliensis Williams				Tu		
Spirifer perextensus Meek and Worthen			Co			
Spirifer pertenuis Hall				H		
Spirifer pharovicinus A. Winchell					Hu	
Spirifer pinonensis Meek		ED		MD		ND
Spirifer pluto Clarke					G	
Spirifer rectiplicatus (Conrad)		×?				
Spirifer saffordi Hall	×					
Spirifer segmentus Hall			Co			
Spirifer strigosus Meek. Devonian.						
*Spirifer subattenuatus Hall						C
Spirifer subdecussatus Whiteaves				H		
Spirifer submucronatus Hall		×				
Spirifer substrigosus Webster						C
Spirifer subvaricosus Hall and Whitfield				H?		
Spirifer tenuis Hall				H		
Spirifer tenuistriatus Hall	×					
Spirifer tribulis Hall		×				
Spirifer tullius Hall				H		

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Cornif-erous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Spirifer urbanus Calvin				H		
Spirifer varicosus Hall			Co			
Spirifer whitneyi Hall						C
Spirifer williamsi Hall and Clarke						C
Spirifer worthenanus Schuchert		×				
Spirifer wortheni Hall				H		
Stringocephalus burtini Defrance				MD		
Strophalosia hystricula Hall						C
Strophalosia muricata Hall						C
Strophalosia radicans (A. Winchell)				H		
Strophalosia rockfordensis Hall						C
Strophalosia truncata (Hall)				M, H	P	I
Stropheodonta alveata Hall			Co			
Stropheodonta arcuata Hall						C
Stropheodonta beckii Hall	×					
Stropheodonta blainvillii (Billings)		ED				
Stropheodonta callawayensis Swallow				H		
Stropheodonta callosa Hall			Co			
Stropheodonta calvini Miller						C
Stropheodonta canace Hall and Whitfield						C
Stropheodonta cincta A. Winchell				H		
Stropheodonta concava Hall			Co	H		
Stropheodonta (?) costata Owen				H		
Stropheodonta crebristriata Hall			Co			
Stropheodonta demissa (Conrad)				MD		ND
Stropheodonta demissa imitata A. Winchell				H		
Stropheodonta erratica A. Winchell				H		
Stropheodonta fieldeni Etheridge		ED				
Stropheodonta galatea (Billings)		ED				
Stropheodonta hemispherica Hall			Co			
Stropheodonta inæquiradiata Hall			Co			
Stropheodonta inæquistriata (Conrad)			Co	M, H		
Stropheodonta indenta (Conrad)	×					
Stropheodonta interstrialis (Phillips)				MD		
Stropheodonta interstrialis (Vanuxem)						I
Stropheodonta iowensis Owen						ND?
Stropheodonta irene (Billings)			Co			
Stropheodonta junia Hall				H		
Stropheodonta kemperi Swallow				H		
Stropheodonta linckiæni Hall		×				
Stropheodonta macrostriata (Walcott)		ED				
Stropheodonta magnifica Hall		×				
Stropheodonta magniventra Hall		×				
Stropheodonta mucronata (Conrad)					P	I
Stropheodonta navalis Swallow				H		
Stropheodonta navalis boonensis Swallow				H		
Stropheodonta parva Owen				H		
Stropheodonta parva Hall			Co			
Stropheodonta patersoni Hall		×	Co			
Stropheodonta perplana (Conrad)		×	Co	H		I, C
Stropheodonta perplana nervosa Hall						I

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Strophеodonta perplana tulliensis Williams				Tu		
Strophеodonta planulata Hall	×					
Strophеodonta plicata Hall				H		
Strophеodonta tullia (Billings)			Co			
Strophеodonta variabilis Calvin						C
Strophеodonta varistriata (Conrad)	×					
Strophеodonta varistriata arata Hall	×					
Strophеodonta vascularia Hall		×				
Strophomena (?) elongata Conrad	×					
Strophomena (?) gibbosa Conrad			Co			
Strophonella ampla Hall			Co			
Strophonella cælata Hall						C
Strophonella cavumbona Hall	×					
Strophonella (?) conradi Hall	×					
Strophonella crassa Rowley				H		
Strophonella geniculata (Hall)	×					
Strophonella headleyana Hall	×					
Strophonella leavenworthana Hall	×					
Strophonella punctulifera (Conrad)	×					
Strophonella (?) radiata (Vanuxem)	×					
Strophonella reversa Hall						C
Strophonella schohariensis Castelnau			Co?			
Terebratula elia Hall				MD		
Terebratula jucunda Hall			Co			
Terebratula ontario Hall				H		
Terebratula traversensis A. Winchell				H		
Trematospira costata Hall	×					
Trematospira dubia (Billings)	×					
Trematospira equistriata Hall and Clarke	×					
Trematospira gibbosa Hall				H		
Trematospira hippolyte (Billings)	×					
Trematospira (?) liniuscula A. Winchell				H		
Trematospira maria (Billings)	×					
Trematospira multistriata Hall	×	×				
Trematospira perforata Hall	×					
Trematospira simplex Hall	×					
Trematospira tennesseensis Hall and Clarke	×					
Trigeria gaudryi Œhlert		×				
Trigeria (?) lepida Hall				H		
Trigeria (?) portlandica (Billings)	×					
Tropidoleptus carinatus (Conrad)				M, H		
Tropidoleptus occidens Hall				H		
Uncinulus abruptus (Hall)	×					
Uncinulus campbellanus (Hall)	×					
Uncinulus mutabilis Hall	×					
Uncinulus nobilis (Hall)	×					
Uncinulus nucleolata (Hall)	×					
Uncinulus pyramidatus (Hall)	×					
Uncinulus vellicata Hall	×					
Vitulina pustulosa Hall				H		
Whitfieldella (?) bisulcata (Vanuxem)	×					

Digitized by Google

TABLE VI.—*Devonian Brachiopoda*—Continued.

Species.	Eodevonian.		Mesodevonian.		Neodevonian.	
	Lower Helderberg.	Oriskany.	Schoharie, Corniferous.	Tully, Hamilton, Marcellus.	Portage, Huron, Genesee.	Chemung, Ithaca.
Whitfieldella (?) harpalyce (Billings)	×					
Zygospira (?) subconcava Meek and Worthen	×					
Number of Devonian species, 663.						
Number of species in each division	129	104	128	238	41	117
Number of species common to the Lower Helderberg and the other divisions		8	2	2	1	2
Number of species common to the Oriskany and the other divisions	8		15	7	0	3
Number of species common to the Corniferous and the other divisions	2	15		27	2	7
Number of species common to the Hamilton and the other divisions	2	7	27		12	23
Number of species common to the Genesee-Portage and the other divisions	1	1	4	12		17
Number of species common to the Chemung and the other divisions	2	4	7	24	17	
Species common to the Devonian and Carboniferous systems, 11.						
Number of species passing from each division into the Carboniferous	1	1	1	4	3	10

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda.*

[B = Burlington; EC = Eocarboniferous; K = Keokuk; Ka = Kaskaskia; SL = St. Louis. Species preceded by an obelisk (†) are found in the Devonian also.]

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Acambona osagensis (Swallow)	×				
Acambona prima White		B			
Ambocœlia minuta White	×				
Ambocœlia planoconvexa (Shumard)				×	×
Athyris biloba (A. Winchell)	×				
Athyris (?) corpulenta (A. Winchell)	×				
Athyris densa Hall and Clarke			SL		
Athyris hannibalensis (Swallow)	×				
Athyris incrassata Hall		B			
Athyris intervarica McChesney		B			
Athyris (?) jacksoni (Swallow)				×	
Athyris lamellosa (L'Eveille)	×	K			
Athyris missouriensis (A. Winchell)	×				
Athyris monticola (White)	EC				
Athyris ohioensis (A. Winchell)	×				
Athyris papillioniformis McChesney			Ka		
Athyris (?) perinflata McChesney		K			
Athyris prouti (Swallow)	×				
Athyris ultravarica McChesney		K			
Aulacorhynchus millipunctata (Meek and Worthen)				×	
Beecheria davidsoni Hall and Clarke				×	
Camarophorella lenticularis (White and Whitfield)		B			
Camarophoria (?) bisulcata Shumard				×	
Camarophoria caput-testudinis (White)		B			
Camarophoria explanata (McChesney)			Ka		
Camarophoria occidentalis Miller		B			
Camarophoria ringens (Swallow)		K			
Camarophoria subcuneata Hall			SL		
Camarophoria subtrigona Meek and Worthen		K			
Camarophoria thera Walcott		EC			
Camarophoria (?) wortheni (Hall)			SL		
†Camarotœchia contracta Hall	×				
Camarotœchia sagerana (A. Winchell)	×				
†Camarotœchia sappho Hall	×				
Centronella (?) allii A. Winchell	×				
Centronella (?) crassicardinalis Whitfield			SL		
Centronella (?) flora A. Winchell	×				
Chonetes geniculata White	×				
Chonetes glabra Geinitz				×	
Chonetes granulifera Owen				×	×
Chonetes illinoiensis Worthen		B			
Chonetes logani Norwood and Pratten	×	B			
†Chonetes logani aurora Hall		B			
Chonetes loganensis Hall and Whitfield	×				
Chonetes mesolobus Norwood and Pratten				×	
Chonetes michiganensis Stevens				×	
Chonetes multicosta A. Winchell	×	B			
Chonetes ornata Shumard	×				

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Chonetes parva Shumard				×	
Chonetes permiana Shumard				×	
Chonetes planumbona Meek and Worthen		K			
Chonetes platynotus White				×	
Chonetes pulchella A. Winchell	×				
†Chonetes setigera (Hall)	×				
Chonetes shumardiana de Koninck		K			
Chonetes tumida Herrick	×				
Chonetes variolata d'Orbigny				×	
Chonetes verneuiliana Norwood and Pratten				×	
Chonetes verneuiliana utahensis Meek				×	
Chonopectus fischeri (Norwood and Pratten)	×	B			
Cleiothyris clintonensis (Swallow)			Ka		
Cleiothyris crassicardinalis (White)	×				
Cleiothyris hirsuta (Hall)			SL, Ka		
Cleiothyris missouriensis (Swallow)				×	
Cleiothyris obmaxima (McChesney)		K			
Cleiothyris obvia (McChesney)			Ka		
Cleiothyris orbicularis (McChesney)				×	
Cleiothyris reflexa (Swallow)			SL		
Cleiothyris roissyi (L'Eveille)		K	SL, Ka		
Cleiothyris squamosa (Worthen)			SL		
Crania chesterensis Miller and Gurley			Ka		Ka
Crania lævis Keyes	×				
Crania modesta White and St. John				×	
Crania (?) permiana Shumard				×	
Crania reposita White		B			
Crania rowleyi Gurley	×				
Cryptacanthia compacta White and St. John				×	
†Cryptonella (?) eudora Hall	×				
Cryptonella (?) inconstans (Herrick)	×				
Cryptonella subelliptica Hall and Clarke	×				
Cryptonella alta Hall	×				
Cyrtina acutirostris (Shumard)	×				
Cyrtina burlingtonensis (Rowley)		B			
Cyrtina lachrymosa Hall and Clarke	×				
Cyrtina neogenes Hall and Clarke		B			
Cyrtina triplicata Simpson	×				
Derbya affinis Hall and Clarke				×	
Derbya bennetti Hall and Clarke				×	
Derbya biloba Hall				×	
Derbya broadheadi Hall and Clarke				×	
Derbya (?) costatula Hall and Clarke			Ka		
Derbya crassa (Meek and Hayden)				×	×
Derbya cymbula Hall and Clarke				×	
Derbya kaskaskiensis (McChesney)			Ka		
Derbya keokuk Hall	×	K			
Derbya pratteni (McChesney)				×	
Derbya robusta (Hall)				×	
Derbya ruginosa Hall and Clarke		K			

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Dielasma bovidens (Morton)				×	
Dielasma burlingtonensis White	×				
Dielasma formosa Hall			SL		
Dielasma gorbyi Miller		K			
Dielasma obovata Hall and Clarke				×?	
Dielasma occidentalis (Miller)	×				
Dielasma (?) rowleyi (Worthen)		B			
Dielasma sacculus (Martin)				×	
Dielasma shumardana Miller			Ka		
Dielasma turgida (Hall)			Ka		
Enteletes hemiplicata Hall				×	×
Eumetria (?) altirostris (White)	×				
Eumetria marcyi (Shumard)			SL, Ka		
Eumetria marcyi costata Hall			Ka		
Eumetria woosteri (White)				×?	
Glossina fisbellula Hall and Clarke	×				
Glossina nebraskensis (Meek)				×	
Glossina sedaliensis (Miller)	×				
Glossina waverlyensis (Herrick)	×				
Harttina anna (Hartt)				×	
Hustedia (?) meekana (Shumard)				×	
Hustedia mormoni (Marcou)				×	
Hustedia (?) papillata (Shumard)				×	
Hustedia (?) triangularis (Miller)	×				
Leiorhynchus boonense (Shumard)		B			
Leiorhynchus newberryi Hall	×				
†Leptæna rhomboidalis (Wilckens)	×				
Lingula atra Herrick	×				
Lingula carbonaria Shumard				×	
Lingula crawfordsvillensis Gurley		K			
†Lingula cuyahoga Hall	×				
Lingula gannensis Herrick	×				
Lingula gorbyi Miller	×				
Lingula halli White		B			
Lingula indianensis Miller and Gurley		K			
Lingula meeki Herrick	×				
Lingula melie Hall	×				
Lingula membranacea A. Winchell	×				
Lingula mytiloides Sowerby				×	
Lingula paracletus Hall and Clarke	×				
Lingula parrishi Miller				×	
Lingula tighti Herrick				×	
Lingula umbonata Cox				×	
Lingula varsoviense Worthen			SL		
Lingulodiscina (?) connata Walcott		EC			
Lingulodiscina newberryi Hall	×				
Lingulodiscina pleurites (Meek)	×				
Martinia glabra (Martin)				×	
Martinia glabra contracta Meek and Worthen			Ka		
Martinia lævigata (Swallow)		K			

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Meekella occidentalis (Newberry)				×	
Meekella (?) occidentalis (Swallow)				×	
Meekella pyramidalis (Newberry)				×	
Meekella striatocostata (Cox)				×	×
Meristella (?) incerta Simpson	×				
Nucleospira barrisi White	×				
Orbiculoidea (?) capax (White)	×				
Orbiculoidea capuliformis (McChesney)				×	
Orbiculoidea convexa (Shumard)				×	
Orbiculoidea gallaheri (A. Winchell)	×				
Orbiculoidea hertzeri Hall and Clarke	×				
Orbiculoidea keokuk (Gurley)		K			
Orbiculoidea illinoiensis (Miller and Gurley)				×	
Orbiculoidea magnifica Herrick	×				
Orbiculoidea manhattenensis (Meek and Hayden)				×	
Orbiculoidea missouriensis (Shumard)				×	
Orbiculoidea (?) munda (Miller and Gurley)				×	
Orbiculoidea nitida (Phillips)				×	
Orbiculoidea patellaris (A. Winchell)	×				
Orbiculoidea saffordi (A. Winchell)	EC				
Orbiculoidea sampsoni (Miller)	×				
Orbiculoidea subtrigonalis (McChesney)				×	
Orbiculoidea tenuilineata (Meek and Hayden)				×	
Orbiculoidea utahensis (Meek)				×	
Orbiculoidea varsoviensis (Worthen)		K			
Orthis (?) flava A. Winchell	×				
Orthothetes crenistrius (Phillips)		EC			
Orthothetes desideratus Hall and Clarke	×				
Orthothetes inæqualis (Hall)	×				
Orthothetes inflatus (White and Whitfield)	×				
Orthothetes lens (White)	×				
Orthothetes umbraculum Authors		EC		×	
Proboscidella (?) clava (Norwood and Pratten)				×	
Productella arcuata Hall	×				
Productella concentrica (Hall)	×				
†Productella lachrymosa stigmata Hall	×				
Productella pyxidata Hall	×				
Productella shumardana Hall	×				
†Productella speciosa Hall	×				
Productus alternatus Norwood and Pratten		K			
Productus altonensis Norwood and Pratten			SL		
Productus auriculatus Swallow				×	
Productus bisinuatus Hall			SL		
Productus blairi Miller	×				
Productus boliviensis d'Orbigny				×	
Productus boonensis Swallow				×	
Productus boonensis elevata Swallow				×	
Productus buchianus de Koninck				×	
Productus burlingtonensis Hall		B			
Productus carbonarius de Koninck. Carboniferous.					

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Productus confragosus Conrad				×	
Productus cooperensis Swallow	×				
Productus cora d'Orbigny				×	
Productus cora mogoyoni Marcou				×	
Productus corœformis Swallow			SL		
Productus costatoides Swallow				×	
Productus costatus de Koninck				×	×
Productus curtirostratus A. Winchell	×				
Productus delawari Marcou		EC			
Productus depressus Swallow		K			
Productus dolorosus A. Winchell	×				
Productus duplicostatus A. Winchell	×				
Productus fasciculatus McChesney			Ka		
Productus fentonensis Swallow		K			
Productus fimbriatus Sowerby			SL?	×?	
Productus flexistrius McCoy			Ka		
Productus giganteus (Martin)			EC		
Productus gracilis A. Winchell	×				
Productus gradatus Swallow		K			
Productus granulosus Phillips		K			
Productus hepar Morton				×	
Productus hildrethanus Norwood and Pratten				×	
Productus indianensis Hall			SL		
Productus inflatus McChesney				×	
Productus ivesi Newberry				×	
Productus lævicostus White	×				
Productus lasallensis Worthen				×	
Productus latissimus Sowerby				×?	
Productus leuchtenbergensis de Koninck				×?	
Productus longispinus Sowerby?				×	
Productus longus Meek. Carboniferous.					
Productus magnicostatus Swallow				×	
Productus magnus Meek and Worthen		K			
Productus margaritaceus Phillips				×	
Productus marginicinctus Prout			SL		
Productus mesialis Hall		K			
Productus mesolobus Phillips. Carboniferous.					
Productus mexicanus Shumard				×	
Productus morbillianus A. Winchell		B			
Productus multistriatus Meek. Carboniferous.					
Productus muricatus Norwood and Pratten				×	
Productus nanus Meek and Worthen				×	
Productus nebrascensis Owen				×	×
Productus nevadensis Meek				×	
Productus newberryi Hall	×				
Productus newberryi annosus Herrick	×				
Productus nodocostatus Herrick	×				
Productus nodosus Newberry				×	
Productus norwoodi Swallow				×	
Productus occidentalis Newberry				×	

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Productus ovatus Hall			SL		
Productus parvulus A. Winchell	×				
Productus parvus Meek and Worthen			Ka		
Productus pertenuis Meek				×	
Productus phillipsi Norwood and Pratten. Carboniferous.					
Productus pileolus Shumard				×	
Productus pocillum Morton				×	
Productus popii Shumard				×	
Productus punctatus (Martin)				×	
Productus pustulosus Phillips				×	
Productus raricostatus Herrick	×				
Productus rushvillensis Herrick	×				
Productus scabriculus (Martin)			EC	×	
Productus scitulus Meek and Worthen			SL		
Productus semireticulatus (Martin)		K	SL	×	×
Productus semireticulatus kansasensis Swallow				×	
Productus semistriatus Meek				×	
Productus subhorridus Meek. Carboniferous.					
Productus swallovi Beecher			Ka		
Productus symmetricus McChesney				×	
Productus tenuicostatus Hall			SL		
Productus undiferus de Koninck				×	
Productus viminalis White		B			
Productus wortheni Hall		K			
Productus weyprechti Toula				×	
Ptychospira sexplicata White and Whitfield	×				
Pugnax dawsonianus (Davidson)				×	
Pugnax globulina (Davidson)				×	
Pugnax grosvenori Hall			SL		
Pugnax mutatus Hall		K	SL		
Pugnax ottumwa (White)			SL		
Pugnax pugnus missouriensis (Shumard)	×				
Pugnax rockymontanus (Marcou)				×	
Pugnax striatocostatus (Meek and Worthen)	×				
Pugnax swallovanus (Shumard)				×	
Pugnax utah (Marcou)				×	
Reticularia cooperensis (Swallow)	×				
Reticularia guadalupensis (Shumard)				×	
Reticularia perplexa (McChesney)				×	
Reticularia perplexa striatolineata (Swallow)				×	
Reticularia pseudolineata (Hall)		B, K			
Reticularia setigera (Hall)			Ka		
Reticularia (?) temeraria (Miller)		B			
Reticularia tenuispinata (Herrick)	×				
Reticularia translata (Swallow)			Ka		
Retzia (?) circularis Miller	×				
Retzia (?) plicata Miller	×				
Retzia (?) popeana Swallow	×				
Rhipidomella burlingtonensis Hall		B			
Rhipidomella clarkensis (Swallow)		K			

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Rhipidomella dalyana (Miller)		B			
Rhipidomella dubia Hall			SL		
Rhipidomella michelini (L'Eveille)	×				
Rhipidomella missouriensis (Swallow)	×				
Rhipidomella nevadensis (Meek). Carboniferous.					
Rhipidomella occasus Hall	×				
Rhipidomella oweni Hall and Clarke	×				
Rhipidomella pecosi (Marcou)				×	
Rhipidomella subelliptica (White and Whitfield)	×				
Rhipidomella thiemii (White)	×				
Rhipidomella vanuxemi pulchella Herrick	×				
Rhynchonella acadiensis Davidson				×	
Rhynchonella algeri McChesney				×	
Rhynchonella arctirostrata Swallow			SL		
Rhynchonella barquensis A. Winchell	×				
Rhynchonella camarifera A. Winchell	×				
Rhynchonella carbonaria McChesney				×	
Rhynchonella cooperensis Shumard	×				
Rhynchonella eurekensis Walcott			EC		
Rhynchonella evangelina Hartt				×	
Rhynchonella guadalupe Shumard				×	
Rhynchonella heteropsis A. Winchell	×				
Rhynchonella hubbardi A. Winchell	×				
Rhynchonella ida Hartt				×	
Rhynchonella illinoisensis Worthen				×	
Rhynchonella indentata Shumard				×	
Rhynchonella macra Hall			SL		
Rhynchonella medialis Simpson	×				
Rhynchonella metallica White				×	
Rhynchonella micropleura A. Winchell	×				
Rhynchonella obsolescens Hall	×				
Rhynchonella opposita White and Whitfield	×				
Rhynchonella perrostellata Swallow			SL		
Rhynchonella persinuata A. Winchell	×				
Rhynchonella pleurodon (Phillips)				×	
Rhynchonella ricinula Hall			SL		
Rhynchonella striata Simpson	×				
Rhynchonella subcircularis A. Winchell	×				
Rhynchonella tetraptyx A. Winchell	×				
Rhynchonella texana Shumard				×	
Rhynchonella tuta Miller		B			
Rhynchonella unica A. Winchell	×				
Rhynchonella whitii A. Winchell	×				
Rhynchopora pustulosa (White)	×				
Rhynchospira (?) ashlandensis Herrick	×				
Rhynchospira scansa Hall and Clarke	×				
Romingerina julia (A. Winchell)	×				
Schizophoria resupinata (Martin)		EC			
Schizophoria resupinoides (Cox)				×	
Schizophoria swallovi Hall		B			

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Seminula argentea (Shepard)				×	×
Seminula caput-serpentis (Swallow)				×	
Seminula charitonensis (Swallow)				×	
Seminula claytoni (Hall and Whitfield)	×				
Seminula dawsoni Hall and Clarke				×	
Seminula formosa (Swallow)		K			
Seminula hawni (Swallow)				×	
Seminula maconensis (Swallow)				×	
Seminula parva (Swallow)		K			
Seminula persinuata (Meek). Carboniferous.					
Seminula (?) plattensis (Swallow)				×	
Seminula singletonii (Swallow)				×	
Seminula subquadrata (Hall)			Ka		
Seminula trinuclea Hall			SL		
Seminula wasatchensis (White)				×	
Spirifer acuticostatus de Koninck				×	
Spirifer agelaius Meek		EC			
Spirifer albapinensis Hall and Whitfield	×				
Spirifer annectans Walcott		EC			
Spirifer biplicatus Hall	×				
Spirifer boonensis Swallow				×	
Spirifer cameratus Morton				×	
Spirifer cameratus percrassus Swallow				×	
Spirifer centronatus A. Winchell	×				
Spirifer clavatulus McChesney		B			
Spirifer deltoideus Herrick	×				
Spirifer desideratus Walcott		EC			
Spirifer duplicostus Phillips. Carboniferous.					
Spirifer fastigatus Morton. Carboniferous.					
Spirifer (?) fimbriatus Morton				×	
Spirifer forbesi Norwood and Pratten		B			
Spirifer fultonensis Worthen				×	
Spirifer grimesi Hall	×	B			
Spirifer imbrex Hall		B			
Spirifer incertus Hall		B			
Spirifer increbescens Hall			Ka		
Spirifer increbescens americanus Swallow			Ka		
Spirifer increbescens transversalis Hall			Ka		
Spirifer kelloggi Swallow		K			
Spirifer keokuk Hall		K			
Spirifer keokuk shelbyensis Swallow			SL		
Spirifer lateralis Hall			SL		
Spirifer latior Swallow	×				
Spirifer leidyi Norwood and Pratten			SL		
Spirifer leidyi chesterensis Swallow			Ka		
Spirifer leidyi merimacensis Swallow			SL		
Spirifer littoni Swallow			SL		
Spirifer logani Hall		K			
Spirifer marcoui Waagen				×	
Spirifer marionensis Shumard	×				

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Spirifer meeki Swallow		B			
Spirifer mexicanus Shumard				×	
Spirifer missouriensis Swallow	×				
Spirifer mortonanus Miller		K			
Spirifer mundulus Rowley		B			
Spirifer mysticensis Meek		EC			
Spirifer neglectus Hall		K			
Spirifer newberryi Hall	×				
Spirifer novamexicanus Miller		B			
Spirifer oregonensis Shumard				×	
Spirifer osagensis Swallow	×				
Spirifer ovalis Phillips. Carboniferous.					
Spirifer peculiaris Shumard	×				
Spirifer rockymontanus Marcou				×	
Spirifer rostellatus Hall		K			
Spirifer rostratus Morton				×	
Spirifer scobina Meek. Carboniferous.					
Spirifer sillanus A. Winchell	×				
Spirifer striatiformis Meek	×				
Spirifer striatus (Martin)	×	B			
Spirifer subæqualis Hall			SL		
†Spirifer subattenuatus Hall	×				
Spirifer subcardiformis Hall			SL		
Spirifer suborbicularis Hall		K			
Spirifer subrotundatus Hall	×				
Spirifer sulciferus Shumard				×	
Spirifer taneyensis Swallow	×				
Spirifer tenuicostatus Hall		K	SL		
Spirifer tenuimarginatus Hall		K			
Spirifer texanus Meek				×	
Spirifer trigonalis Martin			EC		
Spirifer vernonensis Swallow	×				
Spirifer vernonensis ozarkensis Swallow	×				
Spirifer waverlyensis A. Winchell	×				
Spirifer winchelli Herrick	×				
Spiriferina aciculifera Rowley	×				
Spiriferina billingsi Shumard				×	
Spiriferina binacuta A. Winchell		B			
Spiriferina clarksvillensis A. Winchell	×				
Spiriferina cristata (Schlotheim)				×	
Spiriferina depressa Herrick	×				
Spiriferina gonionota Meek				×	
Spiriferina norwoodana (Hall)			SL		
Spiriferina octoplicata (Sowerby)				×	
Spiriferina pulchra Meek				×	
Spiriferina solidirostris White	×				
Spiriferina spinosa (Norwood and Pratten)			Ka		
Spiriferina subelliptica (McChesney)		K			
Spiriferina subtexta White		B			
Spiriferina transversa (McChesney)			Ka		

Digitized by Google

TABLE VII.—*Carboniferous and Permian Brachiopoda*—Continued.

Species.	Eocarboniferous.			Mesocarboniferous.	Neocarboniferous.
	Kinderhook.	Keokuk, Burlington.	Kaskaskia, St. Louis.	Coal Measures.	Permian.
Streptorhynchus (?) multistriata Meek and Hayden	.....	.....	.....	×	.....
Streptorhynchus ulrichi Hall and Clarke	.....	.....	Ka	.....	.....
Stricklandinia (?) subquadrata Herrick	.....	.....	.....	×	.....
Strophalosia beecheri Rowley	×	.....	.....	.....	.....
Strophalosia cymbula Hall and Clarke	.....	K	.....	.....	.....
Strophalosia (?) guadalupensis (Shumard)	.....	.....	.....	×	.....
Strophalosia keokuk Beecher	.....	K	.....	.....	.....
Strophalosia nummulina A. Winchell	×	.....	.....	.....	.....
Strophalosia scintilla Beecher	×	.....	.....	.....	.....
Strophalosia spondyliformis (White and St. John)	.....	.....	.....	×	.....
Strophomena (?) nassula Conrad. Carboniferous.					
Syringothyris angulata Simpson	×	.....	.....	.....	.....
Syringothyris carteri (Hall)	×	B	.....	.....	.....
Syringothyris extenuata (Hall)	×	.....	.....	.....	.....
Syringothyris gigas (Troost). Lower Carboniferous.					
Syringothyris herricki Schuchert	×	.....	.....	.....	.....
Syringothyris missouri Hall and Clarke	×	.....	.....	.....	.....
Syringothyris (?) plena (Hall)	.....	B	.....	.....	.....
Syringothyris randalli Simpson	×	.....	.....	.....	.....
Syringothyris texta (Hall)	×	K	.....	.....	.....
Terebratula bisacula McChesney	.....	.....	Ka	.....	.....
Terebratula brevilobata Swallow	.....	.....	SL	.....	.....
Terebratula inornata McChesney	.....	K	SL	×	.....
Terebratula lapillus Morton	.....	.....	.....	×	.....
Terebratula mexicana Hall	.....	.....	.....	×?	.....
Terebratula perinflata Shumard	.....	.....	.....	×	.....
Terebratula subretziaforma McChesney	.....	.....	Ka	.....	.....
Terebratula swallovana Miller	.....	.....	Ka	.....	.....
Terebratula utah Hall and Whitfield	×	.....	.....	.....	.....
Torynifer criticus Hall and Clarke	.....	.....	SL	.....	.....
Number of Carboniferous species, 478.					
Number of species in each division	156	93	74	158	9
Number of species common to the Kinderhook and the other divisions	.....	9	0	0	0
Number of species common to the Burlington-Keokuk and the other divisions	9	.....	5	4	1
Number of species common to the St. Louis-Kaskaskia and the other divisions	0	5	.....	5	1
Number of species common to the Coal Measures and the other divisions	0	4	5	.....	9
Number of species common to the Permian and the other divisions	0	1	1	9	.....
No species pass from the Carboniferous into the Mesozoic.					

Digitized by Google

TABLE VIII.—*Mesozoic Brachiopoda.*

Species.	Triassic.	Jurassic.	Lower Cretaceous.	Upper Cretaceous.
Cistella beecheri Clark				×
Cistella plicatilis Clark				×
Discina (?) pileolus Whiteaves			×	
Discina (?) semipolita Whiteaves				× ?
Discina (?) vancouverensis Whiteaves				× ?
Kingena leonensis (Conrad)			×	
Kingena wacoensis (Roemer)			×	
Lingula brevirostris Meek and Hayden		×		
Lingula nitida Meek and Hayden				×
Lingula shumardi Cragin			×	
Lingula subspatulata Hall and Meek				×
Rhynchonella æquiplicata Gabb	×			
Rhynchonella gnathophora Meek		×		
Rhynchonella halli Gabb	×			
Rhynchonella lacunosa (Schlotheim)		×		
Rhynchonella lacunosa arolica Oppel		×		
Rhynchonella lingulata Gabb	×			
Rhynchonella maudensis Whiteaves				× ?
Rhynchonella myrina Hall and Whitfield		×		
Rhynchonella plicatilis (Sowerby)				× ?
Rhynchonella schucherti Stanton				×
Rhynchonella taylorianа Lea. Habana, Cuba		× ?		
Rhynchonella whitneyi Gabb				×
Spiriferina (?) alia Hall and Whitfield	×			
Spiriferina borealis Whiteaves	×			
Spiriferina homfrayi (Gabb)	×			
Spiriferina obtusa (Gabb)	×			
Terebratella californica Stanton				×
Terebratella (?) dubitanda (Cooper)				× ?
Terebratella (?) imbricata (Cooper)				× ?
Terebratella obesa Gabb				×
Terebratella plicata (Say)				×
Terebratella vanuxemi Lyell and Forbes				×
Terebratula augusta Hall and Whitfield	×	×		
Terebratula dorenbergi Felix. Mexico		×		
Terebratula harlani Morton				×
Terebratula helena Whitfield				×
Terebratula humboltensis Gabb	×			
Terebratula liardensis Whiteaves	×			
Terebratula poeyana Lea. Habana, Cuba		× ?		
Terebratula repellini d'Orbigny. Mexico		×		
Terebratula robusta Whiteaves		× ?		
Terebratula semisimplex White	×			
Terebratula cfr. zieteni Loriol. Mexico		×		
Terebratulina atlantica (Morton)				×
Terebratulina filosa Conrad				× ?
Terebratulina floridana (Morton)				×
Terebratulina guadalupæ (Roemer)				×
Waldheimia (?) catorcensis Aguilera. Mexico		×		
Number of Mesozoic species, 49.				
Number of species in each system	11	13	4	22

Digitized by Google

TABLE IX.—*Cenozoic and Recent Brachiopoda.*

Species.	CENOZOIC.		RECENT.	
	Eocene.	Neocene.	North and Central American Atlantic.	North and Central American Pacific.
Discinisca lugubris (Conrad)		×		
Discinisca multilineata (Conrad)		×		
Hemithyris psittacea (Chemnitz)		×		
Rhynchonella wilmingtonensis (Lyell and Sowerby)	×			
Terebratula canipes Ravenel	×			
Terebratula carneoidea Guppy. Trinidad	×			
Terebratula demissirostra Conrad	×			
Terebratula lecta Guppy. Trinidad	×			
Terebratula nitens (Conrad)		×		
Terebratula trinitatensis Guppy. Trinidad	×			
Terebratulina gracilis (Schlotheim)	×			
Terebratulina lachryma (Morton)	×			
Terebratulina tejonensis Stanton	×			
Waldheimia kennedyi Dall		×		
Number of species in each division	9	5		
Atretia gnomon Jeffrys			×	
Cistella cistellula (Wood)			×	
Dallina floridana (Pourtales)			×	
Discinisca atlantica (King)			×	
Discinisca cumingi (Broderip)				×
Frieleia halli Dall				×
Glottidia albida (Hinds)			×	×
Glottidia antillarum (Reeve)				×
Glottidia audebarti (Broderip)				×
Glottidia palmeri Dall				×
Hemithyris cranoana Dall				×
Hemithyris psittacea (Chemnitz)		×	×	×
Krausina pisum (Lamarck)				×
Lacqueus californicus (Koch)				×
Lacqueus jeffreysi Dall				×
Lacqueus vancouverensis Davidson				×
Liothyrina bartletti (Dall)			×	
Liothyrina clarkeana Dall			×	
Macandrevia americanum Dall				×
Macandrevia craniella Dall				×
Macandrevia cranium (Müller)			×	
Macandrevia diamantina Dall			×	×
Magasella aleutica Dall				×
Magasella labradorensis (Sowerby)			×	
Magasella radiata Dall			×	×
Platidia anomioides (Phillippi)				×
Terebratalia obsoleta Dall				×
Terebratalia occidentalis Dall				×
Terebratalia transversa (Sowerby)				×
Terebratella frielii Davidson			×	
Terebratella pulvinata (Gould)				×
Terebratella spitzbergensis Davidson			×	
Terebratulina caput-serpentis (Linné)				×
Terebratulina küensis Dall and Pillsbry				×
Terebratulina murrayi Davidson			×	
Terebratulina septentrionalis Couthouy			×	
Number of species in each ocean			15	24

Digitized by Google

TABLE X.—*South American fossil Brachiopoda.*

[J = Jurassic. Species preceded by an asterisk (*) are found in North America also.]

Species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Carboniferous.	Jurassic, Triassic.	Cretaceous.	Tertiary.
* Amboccelia planoconvexa (Shumard)					×			
* Amphigenia elongata (Vanuxem)				×				
Anabia paraia Clarke			×					
* Anoplotheca flabellites (Conrad)				×				
* Camarotœchia dotis Hall				×				
Centronella (?) arcii A. Ulrich				×				
Centronella (?) silvetii A. Ulrich				×				
Chonetes amazonica Derby					×			
Chonetes (?) arcii A. Ulrich				×				
Chonetes comstockii Rathbun				×				
Chonetes curuaensis Rathbun				×				
Chonetes falklandica (Morris and Sharpe)				×				
Chonetes freitassii Rathbun				×				
* Chonetes glabra Geinitz					×			
* Chonetes granulifera Owen					×			
Chonetes herbert-smithi Rathbun				×				
Chonetes onettiana Rathbun				×				
Chonetes rucki A. Ulrich				×				
Chonetes stübeli A. Ulrich				×				
* Chonetes variolata d'Orbigny					×			
* Chonostrophia complanata Hall?				×				
* Cleiothyris roissyi (L'Eville)					×			
Clitambonites adscendens (Pander?)		×						
Cyrtina (?) curupira Rathbun				×				
Dalmanella (?) nettoana (Rathbun)*				×				
Derbya correanus (Derby)					×			
Dielasma hochstetteri (Toula)					×			
Dielasma itaitubensis (Derby)					×			
Enteletes andii (d'Orbigny)					×			
Enteletes gaudryi (d'Orbigny)					×			
Glossina dubia (d'Orbigny)		×						
* Glossina trentonensis (Conrad?)		×						
Harttina coutinhoana (Derby)					×			
* Hustedia mormoni (Marcou)					×			
Leptæna (?) stelzneri Kayser		×						
Lingula coheni A. Ulrich				×				
Lingula ererensis Rathbun				×				
Lingula gracana Rathbun				×				
Lingula metensis Terquem						J		
Lingula munsteri d'Orbigny		×						
Lingula plagemanni Möricke						J		
Lingula rodriguezii Rathbun				×				
* Lingula spatulata Vanuxem				×				
Lingula stantoniana Rathbun				×				
Lingula submarginata d'Orbigny		×						
Lingula truncata Sowerby							×	
Meristella riskowyi A. Ulrich				×				
Notothyris (?) smithii Derby				×				
Orbiculoidea baini Morris and Sharpe				×				
* Orbiculoidea lodensis (Vanuxem)				×				

Digitized by Google

TABLE X.—*South American fossil Brachiopoda*—Continued.

Species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Carboniferous.	Jurassic. Triassic.	Cretaceous.	Tertiary.
Orthis buchi d'Orbigny					×			
Orthis calligramma (Davidson) Kayser		×						
Orthis concinna Morris and Sharpe				×				
Orthis disparilis Kayser		×						
Orthis humboldti d'Orbigny			×					
Orthis (?) laticostata d'Orbigny				×				
Orthis lenticularis Wahlenberg ?	×							
Orthis obtusa Pander		×						
Orthis (?) pectinata d'Orbigny				×				
Orthis saltensis Kayser	×							
Orthis (?) sulivanti Morris and Sharpe				×				
Orthis (?) tenuis Morris and Sharpe				×				
Orthis vespertilio Sowerby		×						
Orthothetes agassizi (Rathbun)				×				
Orthothetes tapajotensis (Derby)					×			
Orthotichia morganiana (Derby)					×			
*Plectambonites sericea (Sowerby)		×						
Productella mæcurnensis Rathbun				×				
Productus batesianus Derby					×			
*Productus boliviensis d'Orbigny					×			
Productus capacii d'Orbigny					×			
Productus chandlessii Derby					×			
Productus clarkianus Derby					×			
*Productus cora d'Orbigny					×			
*Productus costatus (Sowerby) de Koninck					×			
Productus humboldti d'Orbigny					×			
*Productus longispinus Sowerby ?					×			
Productus papilio Gabb					×			
Productus peruvianus d'Orbigny					×			
Productus reticulatus Gabb					×			
Productus rhomianus Derby					×			
*Productus semireticulatus (Martin)					×			
Productus villiersi d'Orbigny					×			
Productus wallacianus Derby					×			
*Reticularia perplexa (McChesney)					×			
Retzia (?) jamesiana Rathbun				×				
Rhipidomella hartti (Rathbun)				×				
Rhipidomella inca (d'Orbigny)				×				
Rhipidomella penniana Derby					×			
Rhynchonella ænigma (d'Orbigny)						J		
Rhynchonella anduln Gottsche						J		
Rhynchonella antisiensis (d'Orbigny)				×				
Rhynchonella antonii Gabb							× ?	
Rhynchonella belemnitica Quenstedt						J		
Rhynchonella caracolensis Gottsche						J		
Rhynchonella ererensis Rathbun				×				
Rhynchonella manfiasensis Möricke						J		
Rhynchonella pipira Derby					×			
*Rhynchonella pleurodon (Phillips)					×			
Rhynchonella plicatissima Quenstedt						J		
Rhynchonella subtetræda (Conrad)							× ?	

Digitized by Google

TABLE X.—*South American fossil Brachiopoda*—Continued.

Species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Carboniferous.	Jurassic, Triassic.	Cretaceous.	Tertiary.
Rhynchonella tetræda (Sowerby)						J		
Rhynchonella triplicata Quenstedt						J		
Scaphiocœlia boliviensis Whitfield				×				
Schizophoria cora (d'Orbigny)					×			
*Seminula argentea (Shepard)					×			
Seminula titicacensis (Gabb)					×			
Spirifer antarcticus Morris and Sharpe				×				
Spirifer buarquianus Rathbun				×				
Spirifer boliviensis d'Orbigny				×				
Spirifer chuquiscus Ulrich				×				
Spirifer condor d'Orbigny					×			
*Spirifer duodenarius Hall				×				
Spirifer elizæ Rathbun				×				
Spirifer hartti Rathbun				×				
Spirifer hawkinsi Morris and Sharpe				×				
Spirifer mæcuruensis Rathbun				×				
*Spirifer murchisoni Castelnau				×				
Spirifer orbignii Morris and Sharpe				×				
Spirifer pedroanus Rathbun				×				
Spirifer pentlandi d'Orbigny					×			
Spirifer quichuus d'Orbigny				×				
*Spirifer rockymontanus Marcou					×			
Spirifer valenteanus Rathbun				×				
Spirifer vogeli von Ammon				×				
*Spiriferina cristata (Schlotheim)					×			
Spiriferina cfr. münsteri Davidson						J		
Spiriferina rostrata Schlotheim						J		
*Spiriferina spinosa (Norwood and Pratten)					×			
Spirigerella derbyi Waagen					×			
Streptorhynchus hallianus Derby					×			
Strophalosia cornelliana Derby					×			
*Strophcodonta perplana (Conrad)				×				
Strophomena (?) talacastrensis Kayser		×						
Terebratula bicanaliculata Schlotheim						J		
Terebratula chilensis d'Orbigny								×
Terebratula copiapensis Möricke						J		
Terebratula derbyana Rathbun				×				
Terebratula domeykana Bayle and Coquand						J		
Terebratula emarginata Sowerby						J		
Terebratula ficoides Bayle and Coquand						J		
Terebratula gottschii Steinman						J		
Terebratula hohmanni Möricke						J		
Terebratula ignaciana d'Orbigny						J		
Terebratula lacunosa Schlotheim						J		
Terebratula meridionalis Conrad							×	
Terebratula patagonica Sowerby								×
Terebratula perforata Piette						J		
Terebratula perovalis Sowerby						J		
Terebratula punctata Sowerby						J		
Terebratula raimondiana Gabb							×?	
Terebratula subexcavata Conrad							×	

Digitized by Google

TABLE X.—*South American fossil Brachiopoda*—Continued.

Species.	Cambrian.	Ordovician.	Silurian.	Devonian.	Carboniferous.	Jurassic, Triassic.	Cretaceous.	Tertiary.
Terebratula subovoides Roemer	.....	.....	.....	.....	.....	J	.....	.....
Terebratula subnumismalis Davidson	.....	.....	.....	.....	.....	J	.....	.....
Trigeria (?) margarida (Derby)	.....	.....	.....	×	.....	.....	.....	.....
Trigeria (?) wardiana (Rathbun)	.....	.....	.....	×	.....	.....	.....	.....
Tropidoleptus carinatus (Conrad)	.....	.....	.....	×	.....	.....	.....	.....
Vitulina pustulosa Hall	.....	.....	.....	×	.....	.....	.....	.....
Number of South American species, 159.								
Number of species in each system	2	12	2	61	47	26	6	2
Number of species common to South and North America, 28.								

Digitized by Google

CHAPTER II.

BRACHIOPOD TERMINOLOGY APPLIED TO FOSSIL FORMS.

Adductor muscles.—In the Protremata and Telotremata these muscles have their ventral insertion one on either side of the central axis, between the diductors. In passing to the dorsal valve they divide into four, and produce in that shell the two pairs of principal scars known as the anterior and posterior adductors. By contraction these muscles close the shell. In the Neotremata they are the essential muscles, so far as scars in the fossil shells are concerned, the anterior adductors closing the valves, while the posterior pair serves to open the valves. In the Atremata there is a simple pair of adductors placed near the anterior extremity of the visceral area.

Anterior region.—That portion of the shell in front of the transverse axis and opposite the pedicle opening.

Apex.—The place of initial shell growth. It may be the most posterior portion of the valve or may be situated near the transverse axis.

Brachidium (Hall and Clarke).—The calcareous brachial supports of the Spiriferacea and Terebratulacea.

Cardinal area.—A more or less well-developed triangular area on each side of the delthyrium, distinctly set off from the general surface of the shell. It is best developed on the ventral valve of articulate brachiopods, but is also present on the dorsal valve, and generally in a rudimentary condition in many inarticulate species. See *Deltidium.*

Cardinal extremities.—The terminations of the hinge line.

Cardinal process.—A variously modified apophysis, situated posteriorly at the center of the hinge of the dorsal valve in articulate brachiopods. To it are attached the diductor muscles, which by their contraction serve to open the valves anteriorly.

Cardinal slopes.—The inclined surfaces extending from the umbonal slopes to the hinge margins.

Chilidium (Beecher).—A plate, in appearance similar to the deltidium, covering the exterior portion of the cardinal process in many Protremata. Its development does not begin until early neanic or later growth, and is probably secreted by the dorsal mantle lobe.

Crura.—Processes on the dorsal hinge plate of the Telotremata and some Protremata, to which are attached the fleshy brachia and brachidia. These usually form the inner walls of the dental sockets, and may be supported by septal plates.

Cruralium (Hall and Clarke).—The dorsal equivalent of the ventral spondylium, being formed by the convergence or union of the crural plates in the Pentameracea.

Digitized by Google

Delthyrium (Hall and Clarke).—The triangular aperture transecting medially the cardinal area, or the posterior surface from the apex to the posterior margin of the ventral valve, through some portion of which the pedicle passes. It has also been termed the *fissure* or *foramen*. The delthyrium may or may not be closed by a deltidium or deltidial plates.

Deltidium.—A plate of one piece which grows over the delthyrium of many Protremata and some Neotremata. In the early larval stage of Thecidium this plate begins as a secretion from the dorsal side of the body segment, and becomes anchylosed to the ventral valve in the phylembronic stage, subsequent additions being secreted by the body wall and pedicle. The convex or concave central portion of the ventral cardinal area in some Atremata is not homologous with the deltidium. It is but a part of the area, and does not have its origin in the prodeltidium, as in Thecidium.

Deltidial plates.—Two plates growing medially from the walls of the delthyrium after neanic growth. These usually unite medially, and close the delthyrium more or less completely. They are restricted to the Telotremata, and are secreted by extensions of the ventral mantle lobe. Hall and Clarke introduced the terms *deltarium* and *deltaria* for the same plates, and for the coalesced condition of the deltaria, Bronn's *pseudodeltidium*.

Dental plates.—Vertical plates supporting the teeth of the ventral valve.

Dental sockets.—Excavations in the dorsal cardinal margin in which the teeth of the ventral valve articulate. The inner wall of the socket is elevated and forms the base of the crural plate.

Diductor muscles.—In the Protremata and Telotremata the principal pair of diductor muscles has the larger end attached to the ventral valve near the anterior edge of the visceral area, while the other end has its insertion on the anterior portion of the cardinal process. There is another pair of small accessory diductor muscles, but these are seldom shown in fossil shells. By contraction these muscles open the valves.

Dorsal valve.—Usually the smaller and imperforate valve and the one to which the brachia are always attached. *Brachial*, *hæmal*, *socket*, and *entering* valves are other terms more rarely employed.

Ephebic (Hyatt, emend. Bather and Buckman).—Designating the mature shell.

Foramen.—A small circular passage through the deltidium or deltidial plates, either below or at the apex of the ventral valve. Sometimes the foramen encroaches by abrasion upon the umbo of the ventral valve.

Genital markings.—Radial markings or pits within the posterior portion of the visceral space, indicating the position and extent of the genitalia.

Digitized by Google

Gerontic (Hyatt, emend. Bather and Buckman).—Designating old age. It is indicated in the ontogeny of many species of brachiopods by extreme thickness of the valves, obesity, or by numerous, crowded growth lines near the anterior margin, a condition which sometimes produces truncation and absence of striæ at the margin.

Hinge line.—The line along which articulation takes place.

Jugum (Hall and Clarke).—The transverse band and its accessory processes uniting the spiralia. When this band is medially incomplete the parts are termed *jugal processes.*

Lateral areas.—That portion of the shell on each side of the ventral axis.

Listrium (Hall and Clarke).—In some Neotremata a plate closing the progressive track of the pedicle opening or pedicle cleft, posterior to the apex of the ventral valve.

Longitudinal axis.—A median line through the shell from the beak to the opposite margin.

Loop.—The calcareous brachial supports of the Terebratulacea. It is usually composed of descending and ascending lamellæ, united by a transverse band.

Median septum.—An internal vertical plate commonly developed along the vertical axis and between the muscles of the ventral valve. Sometimes there is also a dorsal median septum. Lateral septa are rarely developed.

Neanic (Hyatt, emend. Bather and Buckman).—Designating youthfulness, or the stage in which specific characters begin to develop.

Nepionic (Hyatt).—Designating the smooth-shell stage succeeding the protegulum.

Pallial sinuses.—Two convergent or divergent primary sinuses of the circulatory system, traversing the mantle and originating in the posterior medial region. They usually have numerous secondary branches, and both often leave impressions in the shell.

Pedicle.—The flexible muscular organ of the ventral valve by means of which brachiopods may be attached to extraneous objects.

Pedicle muscles.—In the Protremata and Telotremata one pair originates on the ventral valve at points just outside and behind the diductors and another on the dorsal valve behind the posterior adductors, while the opposite ends of both are attached to the pedicle. Besides these, there is an unpaired muscle lying at the base of the pedicle, attaching it closely to the ventral valve.

Platform.—See *Spondylium.*

Posterior region.—That portion of the shell back of the transverse axis and toward the beak, or apex.

Primary lamellæ.—The primary descending bands of the spiralia, the posterior ends being attached to the crura.

Prodeltidium (Hall and Clarke restricted).—The third shell plate developed in the earlier embryonic growth of species of Atremata,

Digitized by Google

Neotremata, and Protremata, and subsequently becoming more or less firmly attached to either the dorsal (Atremata) or ventral valve.

Protegulum (Beecher).—The initial shell of brachiopods. It is smooth and of microscopic size, in outline being semicircular or arcuate, and without cardinal areas.

Protractor muscles.—In the Lingulacea one pair has the ventral ends fastened at the anterior extremity of the visceral area, extending backward and inserted near the lateral margin of the dorsal valve, outside the rotators. A second pair originates just behind the adductors of the ventral valve, and is inserted posterior to the first pair. These muscles draw the dorsal valve forward. They are apparently present in the Obolidæ and Trimerellidæ, but their position is different.

Pseudodeltidium.—Properly this term applies only to the united condition of the deltidid plates in the Protremata and Telotremata. It is provisionally applied to the concave or convex medial portion of the cardinal areas in Atremata and Protremata.

Retractor muscles.—In the Atremata these extend from the outer lateral margins of the visceral area in the ventral valve to its anterior extremity in the dorsal valve, and serve to readjust the dorsal shell.

Rotator muscles.—In Lingulacea these are situated posteriorly just in advance of the umbonal muscle, two on one side and one on the other. By their contraction the dorsal valve turns alternately first in one direction and then in the other.

Septal plates.—Plates supporting the crural processes, also known as *crural plates.*

Spondylium.—A plate in the Pentameracea, formed by the union of converging dental plates, to the upper surface of which are attached the adductor, diductor, and pedicle muscles. The spondylium may rest upon the ventral valve or may be supported by a median septum. This plate is rarely present in the Telotremata, but more commonly in the Atremata, where it is known as the *platform.* There is sometimes developed in the dorsal valve a plate similar in appearance to the spondylium, but different in origin, and known as the *cruralium.*

Spiralia (Beecher).—The calcareous spiral brachial supports in the Spiriferacea. A connecting jugum may be present or absent.

Syrinx.—A tubular structure developed in the delthyrium of some Spiriferacea, opening ventrally and partially inclosing the pedicle.

Teeth.—Two processes of the ventral valve of articulate brachiopods, serving for articulation.

Transverse axis.—A line through the shell from right to left, midway between the beak and anterior margin.

Umbo.—The elevated or prominent portion of the valve anterior to the apex.

Umbonal muscle.—A single muscle situated in the umbonal region of most Atremata. By its contraction the valves are opened anteriorly. In Obolus this muscle divides toward the ventral valve.

Digitized by Google

Umbonal slopes.—The inclined surfaces about the umbo and opposite the cardinal slopes.

Ventral valve.—The valve situated on the ventral side of the animal, and having in youth or maturity a delthyrium or pedicle opening through which the pedicle is protruded, except in Iphidea, Obolella, Lingula, etc., where the pedicle protrudes between the valves. When the shell is cemented to foreign bodies it is always by the ventral valve. It is usually the larger and deeper of the two valves. *Pedicle*, *larger*, *dental*, *neural*, and *receiving* valves are synonymous terms.

Digitized by Google

CHAPTER III.

BIOLOGIC DEVELOPMENT OF THE BRACHIOPODA.

ORDINAL DEVELOPMENT.

ATREMATA.

This order, which began in the Lower Cambrian, is represented by 199 species, or over 10 per cent of American Paleozoic brachiopods. Its greatest representation, both in species and genera, was during the Cambrian and Ordovician eras. A very marked decline set in during the Silurian and Devonian, with almost extinction in the Carboniferous, where only Lingula and its subgenus Glossina occur.

The terminal families Trimerellidæ and Lingulidæ contain species which attain the greatest individual growth. Lingulidæ has the longest phylogenetic history. It is the last important and most specialized family of the Atremata, and manifests the greatest persistency and specific differentiation. Lingula, the essential genus of the family, lived at least from the Ordovician system through all succeeding time, and is represented in modern seas. During this enormous period the only change observable is that in the ancient forms the viscera occupied a little more and the brachia somewhat less space.

In the more primitive types of Atremata, Obolacea, the shell is usually much thicker and less chitinous than in the higher or derived families, Lingulacea. The shell is thickest in the Trimerellidæ and thinnest in the Lingulidæ. From their mode of occurrence in rocks it seems probable that Paterinidæ, Obolidæ, and Trimerellidæ (=Obolacea) never lived in the mud or sand of the sea bottom, as did Lingulidæ, Lingulasmatidæ, and probably Lingulellidæ (=Lingulacea).[1] The oboloids in all probability had short pedicles, while the linguloids have very long pedicles. The long, flexible, tubular pedicle of Lingula, associated with the buried habit of the animal, apparently explains

[1]Since all the species of Obolacea are known only as fossils, it may seem hazardous to ascribe to them a mode of living different from that of Lingula. These shells had short peduncles, are round or oval, sometimes very gibbous, always comparatively thick shelled, and not decidedly phosphatic. The writer has never observed any species of this superfamily in situ transverse to sedimentation, or in other words "on edge." In the Lingulacea the peduncle is very long, and the shells are elongate quadrangular, triangular, spatulate, or acuminate, and, as a rule, are decidedly thin and phosphatic. Recent Lingulas all live partially buried in the sea bottom, and not infrequently fossil species are found in situ, on edge, with their apices downward. Lingulops and Lingulasma also have been observed situated on edge. The round, thick shells of Obolacea are strongly contrasted with the elongate thin shells of Lingulacea. These peculiarities are in all probability due to mechanical causes. The Linguloids, with their long, powerful, and flexible peduncles, are buried in the sediments, while the posteriorly pointed shell is an adaptation to the same end, caused by the frequent peduncular pulling on that part of the valves.

Digitized by Google

the cause for the thinness of the shell and the long, narrow, attenuated form of its valves.

The ontogeny of Obolella and Lingula shows that one branch developed directly from the Paterinidæ to Obolidæ and Trimerellidæ, while another branch began in the Obolidæ. The derived branch continued to diverge by changing the thick round shells of the radical stock into thin spatulate or elongate subquadrate valves, first in the Lingulellidæ and culminating in the Lingulidæ. The latter family then gave rise to Lingulasmatidæ, which, in accordance with the law of morphologic equivalents, developed some of the internal diagnostic characters of the terminal family of the first phylum in the platform of the Trimerellidæ.

Hall and Clarke refer the genera of Lingulasmatidæ to Trimerellidæ, and thus the latter family, as understood by them, embraces two stocks having widely separated origins. This is peculiar, since they clearly understand the independent origin of these stocks, as will be seen by the following quotation, but more particularly by their diagram.[1]

There is no single feature in the entire group of the edentulous brachiopods so striking as the great platforms in Trimerella and its allies, and it is rarely that so beautiful and well established an illustration of the attainment of such a remarkable resultant along two distinct lines of development can be presented.

The writer holds that a natural family can have but one stock, a stock can have but one origin.

Nonfunctional articular processes are developed in this order in a number of genera and at various times. Such are slightly developed in Trimerella and Monomorella, and more strongly in Tomasina, Barroisella, and Spondylobolus. In the Neotremata, articulation is also approached in Trematobolus, and in Crania a false hinge is sometimes developed in Ordovician species. A cardinal process so characteristic of the Protremata and Telotremata is faintly developed in Neobolus, Lakmina, and Trimerella of the Atremata.

NEOTREMATA.

The order Neotremata begins in the Lower Cambrian, and is represented by 156 species, or over 8 per cent of the brachiopods of the American Paleozoic. It has considerably fewer species than the Atremata, and exhibits a lack of specific differentiation, such as form and surface ornamentation. This probably is largely due to the fact that the pedicle is very short, or even obsolete, in this order, and that the pedicle foramen is subcentral, producing in the Trematidæ and Craniidæ more or less of a parasitic growth, while in the families Discinidæ and Acrotretidæ the great majority of species are circular or oval, with more or less cone-shaped shells.

As in the Atremata, great tenacity of life is also manifested in this order, since its two essential families, Discinidæ and Craniidæ, have representatives throughout all time since the Ordovician system.

[1] Paleontology of New York, Vol. VIII, Part I, 1892, p. 165.

Digitized by Google

Greatest representation in both genera and species was during the Ordovician, after which generic differentiation was practically restricted to the Discinidæ and Craniidæ. Crania persisted throughout the post-Ordovician, and for longevity equals the atrematous genus Lingula.

The percentage of widely dispersed species is about the same as in the Atremata, and likewise is greatest in those families with the longest phylogenetic history, as Acrotretidæ, Discinidæ, and Craniidæ.

Development was along two lines. In one a broad fissure (the most primitive condition of the pedicle opening in this order) is retained as a mature character (Trematidæ). Later geologically, and at the maturity of the individual in derived forms, the fissure is gradually closed posteriorly, leaving a long, narrow slit, at one end of which the pedicle emerges (Discinidæ). The other line (Acrotretacea) probably developed and inherited holoperipheral growth in the ventral valve, very rapidly producing a small subcentral circular foramen, since this feature is already well developed in the Lower Cambrian Acrotretidæ, and in advance of the greatest development of the Discinidæ. It is probably this second branch that gave origin to the degraded family Craniidæ. The protegulum in the dorsal valve of Acrotretacea is probably always marginal, whereas in the Discinacea it is always more or less central.

It is remarkable that Crania, so unlike other living brachiopods and occurring abundantly in the seas of to-day, has never been completely studied developmentally or ontogenetically. The taxonomic position of the Craniidæ is therefore not actually determined, and Hall and Clarke incline to follow Waagen in regarding the Craniacea as equivalent in rank to the Atremata and Neotremata. These authors write:[1]

> It is nevertheless to be observed that no trace of a former pedicle-slit incision or perforation is found on mature or immature shells, and it would be difficult to comprehend in what manner such an essential modification of the shell could be wholly concealed by later growth. Were the pedicle marginal in primitive growth stages, and subsequently atrophied, the obliteration of the marginal opening by later resorption and growth would be a readily intelligible process. There is, hence, in this default of evidence, a good reason to doubt the close affinities of Crania and Pholidops to the Diacaulia [= Neotremata]. Present knowledge would seem to indicate that they were primarily of the type of the Mesocaulia [= Atremata], and that their resemblance to the Diacaulia is wholly of secondary growth. Waagen's term for this group, Gastropegmata (or Craniacea), may therefore prove to be equivalent to each of these other two divisions.

Brachiopod embryology demands a pedicle in the early stages of Crania. The ventral valve carries the pedicle, and it is always this valve which is attached by cementation or otherwise. The writer has observed in Yale University Museum a specimen of *Pholidops ovata* with a cicatrix of attachment, around which point growth is holoperipheral, as in all Neotremata. Specimens of Pholidops are sometimes preserved with both valves in position and delicately attached to Bryozoa,

[1] Palæontology of New York, Vol. VIII, Part II, 1895, p. 325.

Digitized by Google

from the Falls of the Ohio. These are believed to be actual and not chance attachments. In Crania cementation occurs very early and is complete, causing all obliteration of the protegulum and subsequent stages of growth in the ventral shell. That cementation does obliterate nearly all the younger characters is also shown in the remarkable genera Richthofenia and Ostrea. On the interior of Pholidops and Crania the four large muscular scars, which are more those of the Neotremata than of the Atremata, are arranged medially, in the center of which, probably, was the pedicle opening. Some proof of this is seen in the excavated, posteriorly terminating muscular pit of *Crania ignabergensis*, which, if carried through the valve, will make the pedicle opening subcentral and surrounded by shell deposit. If an Acrotreta, Linnarssonia, or Conotreta became cemented, there would result practically a Crania. In no atrematous brachiopod is there the slightest indication of cementation, but where shell fixation does occur it is always (excepting in Zugmeyeria and Thecocyrtella) in such as have the pedicle very early surrounded by shell matter, as in the Strophomenidæ and Productidæ. For these reasons the characters of Craniacea seem more in accord with the Neotremata than with the Atremata. The characters of Craniacea are certainly not of ordinal importance, and possibly not even of superfamily value.

In the development of its pedicle foramen the family Siphonotretidæ is unlike any other of this order. During neanic growth the pedicle opening was posterior to the protegulum, but later it gradually moves anteriorly through the shell by resorption, producing a narrow slit similar in appearance to that of the Discinidæ. A pedicle foramen of the same nature is also developed in Eichwaldia and Dictyonella of the Protremata. As yet no explanation has been given as to the causes producing this aberrant development. The writer suggests that since these animals had delicate peduncles, with the shell elongate oval and sometimes cone-shaped in form, they probably stood nearly upright on their pedicles in early growth. Shell accretion being more rapid anteriorly, with the ventral side of the animal the larger and heavier, a tendency was initiated for the shell to lean against the ventral side of the peduncle. This pressure would produce resorption of the ventral shell anterior to the pedicle, and eventually, this tendency becoming hereditary, the ventral valve would lie nearly flat, with the pedicle emerging at a great angle subcentrally.

PROTREMATA.

This order is represented by 738 species, or nearly 40 per cent of American Paleozoic brachiopods, and is eminently characteristic of the post-Cambrian Paleozoic systems. Like the Atremata and Neotremata, it is represented in the Lower Cambrian. It was not, however, until Ordovician times that the Protremata attained very rapid evolution. In the Cambrian there are but 4 genera and 22 species, while in

Digitized by Google

the Ordovician there are 20 genera and 173 species, a specific increase of more than seven and one-half times the number in the Cambrian. Greatest generic differentiation occurred during the Silurian, where 30 genera appear. Then began a steady decline, with extinction in the Carboniferous of North America. In the Triassic of Europe this order is sparingly represented by small species, and is there essentially restricted to the family Thecidiidæ, which continues to have living representatives in the Mediterranean Sea.

The widely distributed species gradually increase in percentage from 14 in the Cambrian to 36 in the Carboniferous, and are most marked in the family Productidæ. This family is one of the last of the order to originate.

The largest of all brachiopods occur in this order, in the families Pentameridæ and Productidæ, exceeding the Spiriferidæ of the Telotremata. In the former family greatest size is attained in the Silurian during the acme of the order, and in the Productidæ in the Carboniferous system. *Productus giganteus* of the Lower Carboniferous is the giant of all brachiopods, attaining a diameter of nearly 1 foot. In both these families the earliest species are small, but certain groups gradually attain larger and larger size with geologic time. Upon the appearance of the giants, vitality of the families, as exemplified in specific differentiation and robustness of individuals, is at its highest. After this these families rapidly decline, and the species dwarf far more rapidly than they developed to the climax.

In the Protremata, as in the two previous orders, greatest specific differentiation does not occur in the radical families, but in those of later development. The Kutorginidæ, Clitambonitidæ, and Billingsellidæ are the radical and, geologically, the oldest families of the Protremata. These are best but sparingly developed in the Cambrian, whereas the younger families, Pentameridæ, Strophomenidæ, Productidæ, and Orthidæ, contain over 95 per cent of the species and nearly 90 per cent of the genera. Orthidæ and Strophomenidæ, beginning in the Cambrian, are best developed in the Ordovician and Silurian systems, respectively; while Productidæ, originating in the Silurian, attained a climax in the Carboniferous. The latter family was one of the last of the Protremata to originate and has the shortest geologic history and least generic differentiation, yet many of its species have greater geographic dispersion.

The Protremata are clearly divisible into two phyla, Strophomenacea and Pentameracea. The former superfamily has the greater number of species, and is characterized by the nondevelopment of a spondylium or cruralium. The Pentameracea has, in addition to the deltidium, an internal spoon-shaped plate, or spondylium, serving for the attachment of muscles, and a discrete or united cruralium. The superfamily Strophomenacea in North America has 608 species, and represents the most primitive phylum, since it is far better developed in the Cambrian than

Digitized by Google

is the Pentameracea, and has almost without exception a straight cardinal area. The Pentameracea has 127 species, and its earliest forms also have straight hinge-lines in the 16 species of the families Clitambonitidæ and Syntrophiidæ; but the rostrate family Pentameridæ, which attained maximum development in the Silurian, has 87 species. The Strophomenacea has living species, while the Pentameracea disappeared with the Permian. The cause for the rapid extinction of the latter is probably due to the high degree of specialization expressed by the spondylium.

Two well-marked types of shell form are developed in this order. By far the most prominent is the group which includes the long-hinge families Kutorginidæ, Clitambonitidæ, Billingsellidæ, Strophomenidæ, Productidæ, Thecidiidæ, and Orthidæ. The other group, represented by Pentameridæ, is largely rostrate in form, but occasionally also develops a straight hinge line. This, however, is never so prominent as in the former group. In the Telotremata the general form is rostrate, but very notable exceptions are present in the families Spiriferidæ and Terebratellidæ, and occasionally in the Rhynchonellidæ and Athyridæ. The form of the shell, however, has no great taxonomic value, and can not be accorded more than generic rank. The predominating type of shell form within an order probably has phyletic value, since the oldest protrematous shells are long-hinged, while the telotrematous shells are usually rostrate. Nevertheless, as indicated above, in the derived forms of both orders there are notable exceptions, and these changes are probably always induced by shortening or lengthening of the peduncles. Since Orthorhynchula has a well-developed cardinal area, it is not in itself "evidence of the first significance as indicating the source from which the extensive group of the Rhynchonellas originated."[1] The oldest rhynchonelloids are rostrate shells (*Protorhyncha? minor* and *P.? ambigua* of the Lower Cambrian), and the ontogeny of several species of Rhynchonella and of Zygospira has not revealed a long-hinged stage with cardinal areas. There is, therefore, no conclusive proof for the deduction of Hall and Clarke, "that some of the Rhynchonellidæ, early in their [geologic] history, occasionally retain a well-defined cardinal area, and that, in default of other evidence, the presence of this character may be regarded as indicative of the common origin of Orthis, the Strophomenidæ, and the Rhynchonellas."[2]

In this order far more than in any other is found the closure of the pedicle passage and atrophy of the pedicle, together with peculiar special adaptations which entirely or partially replace the functions of the pedicle. In the family Productidæ the ventral shell develops more or less abundant tubular spines, either along the cardinal line or over the entire valve. These are always most abundant in, or are

[1] Palæontology of New York, Vol. VIII, Part II, 1895, p. 336.

[2] Ibid., p. 342. For further remarks bearing on this subject, see pages 93–95 on the significance of the prodeltidium.

Digitized by Google

restricted to, the posterior region. The functions of the spines are to hold the animal to its place of habitation, for there is no apparent pedicle opening in these shells when mature. In others of the same family the ventral apex is cemented to extraneous objects (Strophalosia), and in still others the spines clasp the object of support when small (*Strophalosia goldfussi* and Etheridgina). In the Strophomenidæ the older species all seem to have functional pedicles throughout life, but in the Devonian, forms occur in which the apex is cemented to foreign objects (Leptænisca). Some of the Middle and Upper Devonian Stropheodontas show no trace of a pedicle opening when adult. In the Carboniferous cementation is far more common, and occurs in Derbya and Streptorhynchus; and when taken in connection with Strophalosia, Chonostrophia, Aulosteges, and Richthofenia, it is seen that nearly all the contemporaneous species of this order have developed other methods for fixation than the normal one. In Richthofenia calcareous cementation is complete, and the modifications resulting therefrom have so changed the shell that the lower or fixed valve is very suggestive of a cyathophylloid coral, not only in form but even in shell structure.

The chief cause for atrophy of the pedicle lies not only in the fact that this organ, in all long-hinged brachiopods, is short, but more particularly in the fact that throughout this order, and in the Acrotretacea of the Neotremata, the young shells always have the pedicle completely surrounded by shell, and thus to a great extent limit its growth. Even among the Orthidæ, where the species geologically older often have thick pedicles, which is indicated by the large open delthyrium, they gradually diminish in size throughout the Paleozoic. In the Strophomenidæ the pedicle is never a thick organ, and shortly after this family gives rise to the Productidæ, in Chonetes, the first appearance of cementation takes place. This mode of attachment constantly increases in the different phyla to the end of the family histories. In the Productidæ the early inheritance of a weak pedicle soon leads to its complete loss by the additional fixation developed. This additional fixation has its first appearance in the cardinal spines of Chonetes, which are periodically developed by mantle extensions. The degeneracy of the pedicle, once well established, is inherited at earlier and earlier periods by acceleration. The spines become more numerous, and are finally developed over the entire ventral valve. In the dorsal valve, the spines are never so long as in the ventral valve, and often are not developed at all, but are replaced by numerous concentric overlapping lamellæ. As the spines begin to develop more numerously and longer, the ventral valve attains more convexity, with a strongly incurved beak and the complete loss of a pedicle opening. Productus, therefore, does not stand erect on the cardinal areas, as in Chonetes, but lies on the ventral shell, anchored by the numerous spines. The spines are of the same nature as the shells, and never flexible. When

Digitized by Google

they came in contact with hard objects during their growth, they followed along or clasped the object of support.

The slender shell-incased pedicle of the Strophomenacea probably leads to the growth of long, straight hinges for additional support, further weakening the pedicle and necessitating accessory fixation in four of its families, and finally occasioning in many species complete loss of this organ at the maturity of the individual. With the exception of the Thecidiidæ, the order Protremata has become nearly extinct since the Jurassic era.

TELOTREMATA.

This order, though but 2 Cambrian and 20 Ordovician forms are known, is represented by 766 species, or about 41 per cent of all American Paleozoic brachiopods. It is as well developed specifically as the Protremata, and exhibits a far greater variety of structures. Telotremata was probably the last order to originate, and has the greatest number and variety of living species. Its highest development is in the Devonian, where 369 species in 50 genera occur, while 109 species are known from the Silurian, a growth more than five times greater than that of the Ordovician system. Here, too, as in the Protremata, considerable time was consumed in establishing a few primitive characters, and these are no sooner obtained than an almost sudden development of great specific and generic differentiation takes place.

It is highly probable that no telotrematous Paleozoic genus continued to live through half the geologic time that Lingula and Crania did. Rhynchonella, a primitive genus of this order, is often said to have continued since the Ordovician, and Terebratula since the Devonian, era. This is now very doubtful, since Hall and Clarke have demonstrated that in all of the Paleozoic forms of these genera where it has been possible to examine their interiors none belong to Rhynchonella or Terebratula. In this catalogue both genera are recognized as occurring in the Paleozoic, but this is due to the fact that the internal structure of those species is not known.

Telotremata has three distinct types of brachial supports, which readily serve to differentiate 3 superfamilies. The simplest, Rhynchonellacea, has but crura, and is represented in the American Paleozoic by 14 genera and 202 species, of which 66 are widely distributed. The superfamily Terebratulacea, having more or less simple V or W shaped brachial supports, is present with 19 genera and 78 species, of which 23 are widely distributed. In the structurally more complex superfamily Spiriferacea, having spiral brachial supports, there are 41 genera and 466 species, and of these 161 become widely distributed. This again confirms the previously noted fact that the groups latest developed have the greatest generic and specific differentiation. In Spiriferacea this likewise occurred in the family Athyridæ.

Digitized by Google

If the percentage of widely distributed species within a superfamily is a criterion of its vitality, it will be seen that the Rynchonellacea begin in the Ordovician with 50 per cent and decline to 23 per cent in the Carboniferous. The Spiriferacea, also beginning in the Ordovician, have 50 per cent of their species widely distributed, becoming reduced to 20 per cent in the Carboniferous. On the other hand, the Terebratulacea were not widely dispersed in the Silurian, whereas in the Devonian their distribution reached nearly 30, increasing to 34 per cent in the Carboniferous. Since no statistics of the European Mesozoic and Cenozoic species of this nature are available, the writer can not determine whether or not the Rhynchonellacea continue to decline with such rapidity. It is known, however, that this superfamily has declined considerably in the Cenozoic and late Mesozoic. After the Triassic the Spiriferacea are essentially represented by Spiriferina, yet it too died out with the Jurassic, while the Terebratulacea, which manifested progressively greater vitality during the Paleozoic, are believed to have continued so nearly throughout the Mesozoic into late Cretaceous time. Since then, however, they have also declined.

In the ontogeny of Dielasma and Zygospira—loop-bearing and spire-bearing genera respectively—Dr. Beecher and the writer have shown that the Terebratulacea may not have been the last superfamily to develop, as was formerly supposed, and that it may have given rise, during early Ordovician times, to the spire-bearing superfamily Spiriferacea. The Terebratulacea probably originated in the Rhynchonellacea, though no loop-bearing species are known until the spire-bearing forms are well advanced, or until early in the Devonian system. While some of the largest species of Terebratulacea are found in the Devonian of America and Europe, yet throughout the Paleozoic this superfamily is not a conspicuous one. In the Jurassic and Cretaceous systems of Europe, however, great specific differentiation and abundant individual development took place. There is but 1 species of this superfamily in the American Silurian, while the Devonian has 50 species in 15 genera, an increase fifty times greater than that of the Silurian. In the Carboniferous a sharp decline set in, and the superfamily is reduced to 30 species and 8 genera.

These facts suggest that either the superfamily Terebratulacea did not originate in American seas or—which seems less probable—that diminutive species occur whose interior characters have escaped detection. Further, since the earliest American primitive genera, Rensselæria and Trigeria of the Lower Devonian, have very large species, neither these nor Centronella can be the earliest adult representatives of this superfamily. When quite young, Zygospira, also, has a "centronella-like loop," and it is possible that the primitive Terebratulacea had their origin before the earliest appearance of Zygospira, or during the earliest part of the middle Ordovician era.

The great majority of telotrematous genera are rostrate in form, but

Digitized by Google

at different times and in separate phyla straight cardinal areas are more or less well developed. In America, the oldest members of this order (*Protorhyncha? minor* and *P.? ambigua*, members of the family Rhynchonellidæ) occur in the Lower Cambrian. In these species, and in the great majority of this family, there is no cardinal area; but occasionally this character is present, the earliest conspicuous example being the Ordovician genus Orthorhynchula. Among the Paleozoic Terebratulacea cardinal areas are seldom developed. A conspicuous exception, however, occurs in Tropidoleptus. But in the Mesozoic and Cenozoic, in the family Terebratellidæ, cardinal areas are very often present, and in living forms are accompanied by a short pedicle. It is, moreover, in the Spiriferacea, the youngest superfamily of the Telotremata to originate, that the greatest development of cardinal areas takes place. The oldest genera of the Spiriferacea are all rostrate, as in the Ordovician Zygospira, Catazyga, and Cyclospira. In the Silurian the Spiriferidæ tend to develop rapidly long, straight, and wide cardinal areas, attaining greatest development in the Devonian and early Carboniferous. This excessive development of cardinal areas is no doubt due to the shortening and decline of the pedicle, since in the Triassic system forms occur in which cementation is complete (Zugmeyeria and Thecocyrtella). Cardinal areas are also developed in other families of the Spiriferacea, but in no case can such be traced to Ordovician long-hinged ancestors.

In this order, more than in the Protremata, internal specialization of the brachia has progressed from a simple to a highly complex condition. In the Protremata, in its latest developed superfamily, Pentameracea, crura are also present, of the same phase of development attained by the Rhynchonellacea, the most primitive superfamily of the Telotremata. In this order, however, there are, with but few exceptions, no internal special structures, as spondylia. The specialization in the Telotremata is expressed in the progressive complication of the calcareous brachial supports. In the most primitive species of the Rhynchonellacea no crura are present (Protorhyncha), but in all later forms these appendages are well developed, and finally in the Trias and Jura attain very great length in Rhynchonellina. In the next more complicated superfamily, Terebratulacea, the crura in the primitive members have united anteriorly, thus forming the simple unchanging loop of Centronella and Rensselæria, which is also known to occur in the very young of some species of the highest superfamily, the Spiriferacea. The geological history of the loop has shown that the brachia have been constantly changing, causing more or less complete resorption of the hard parts and adaptation to later requirements. The progressive development of the loop is also repeated ontogenetically and more or less fully in living terebratuloids.

In Zygospira, the oldest known genus of the suborder Spiriferacea, the primitive loop of Centronella is reproduced in the earliest phase in

Digitized by Google

the development of its brachidium. This is partially resorbed and changed in form, and to it is then added laterally the two spirals and medially the simple or, in the higher forms, the complex processes, or jugum. The volutions of the spirals in the oldest genera geologically are very few, but subsequently they become more numerous, and attain their maximum in the long-hinged Devonian and Carboniferous spirifers, where 35 volutions have been observed, with 24 in Atrypa.

The form of the paired spirals varies but little except under the necessity of conforming to the interior cavity of the valves. Their inclination and direction is a feature of much significance when considered with reference to the development of the entire shell. It is the loop, or to employ a term more appropriate in view of the homologies of the spire-bearing and loop-bearing shells, the *jugum*, however, which is subject to the most frequent variations in form, and which serves as the generic index. When the spirals are directed outward toward the lateral margins of the valves, the jugum seems to be much more variable than in shells where the spirals are introverted or take some intermediate position. In the latter there is a much greater variation in the position of the loop upon the primary lamellæ than occurs in the former.[1]

GENERAL DEVELOPMENT.

In the preceding pages it is shown that the four types of pedicle openings which serve as the prime characters in distinguishing the four orders, Atremata, Neotremata, Protremata, and Telotremata, are present in the oldest division of the Cambrian, the Olenellus zone. From the pre-Cambrian sedimentary rocks, or Algonkian system, practically no fossils are known, though there is evidence in them that life existed. The fact that the Olenellus zone has a varied marine fauna alone indicates that the sea during Algonkian times must have swarmed with living things. When the enormous time represented by the great thickness of North American pre-Cambrian sediments is considered, or that of Bohemia, it is evident that ample time elapsed for life to attain the degree of complexity manifested in the basal Cambrian zone. Kayser says that this pre-Cambrian time was "probably so long that the beginning of the Cambrian period may be considered as comparatively a recent event."[2] Van Hise, in writing on the same subject, says:[3]

If geological history were to be divided into three approximately equal divisions, these divisions would not improbably be the time of the Archean, the time of the clastic series between the Archean and the Cambrian, and the time of Cambrian and post-Cambrian. In this connection it is well to recall that many years ago Logan suggested that the thickness of the Laurentian and Huronian may surpass that of all succeeding formations, and that the appearance of the so-called Primordial fauna may be considered as a comparatively modern event.

In the Lower Cambrian there are not many species of brachiopods, nor is the specific differentiation in any order very varied, indicating

[1] Hall and Clarke, Paleontology of New York, Vol. VIII, Part II, 1895, p. 343.
[2] Text-Book of Comparative Geology, 1893, p. 13.
[3] Sixteenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 760.

Digitized by Google

either that evolution in pre-Cambrian eras was much slower than subsequently or that the class had its origin late in the Algonkian. Cambrian brachiopods usually differ fundamentally from one another, and do not appear to have been persistent, as but 4 of the 22 genera pass into the Ordovician. Differentiation also appears to have been slow during the Lower and Middle Cambrian, but toward the close of this system species begin to be more numerous and varied. In Middle Ordovician times all the orders and superfamilies are well established except Terebratulacea. The zenith of the class was attained in the Silurian and Devonian eras, but decline began during late Devonian, and steadily continued to the close of the Paleozoic. But 7 of the Carboniferous genera are known to have survived the break between the Paleozoic and Mesozoic. During the latter time the spire-bearing brachiopods pass out of existence, while the great Paleozoic superfamily Strophomenacea is represented by a few small species of the Thecidiidæ, which continue to be represented up to the present time. After the Cretaceous system the orders Atremata, Neotremata, and Protremata are represented only by Lingula, Discina, Discinisca, Crania, and Thecidium. The Terebratulidæ may have had their inception below the middle of the Ordovician, but are not a pronounced Paleozoic group. However, in the Jurassic and Cretaceous systems the rocks abound with the shells of this family, and from that time on they are the chief representatives of the class. Lingula and Crania are present in the Ordovician, and, as far as can be determined, have persisted to the present time.

Of the 49 families and subfamilies constituting the class, 43 became differentiated in the Paleozoic, and of these 30 disappeared with it, while but 13 continued from the Paleozoic into the Mesozoic. Of Paleozoic families, 6 are represented by living species, viz, Lingulidæ, Discinidæ, Craniidæ, Thecidiidæ, Rhynchonellidæ, and Terebratulidæ.

Of the 327 genera now in use, 227 had their origin in Paleozoic seas, or nearly 70 per cent of the entire class, and of this great number but 8 are positively known to pass into the Mesozoic, viz, Lingula, Orbiculoidea, Crania, Rhynchonella, Spiriferina, Athyris, Terebratula, and Hemiptychina. Besides these, Streptorhynchus, Cyrtina, Retzia, Martinia, and Martiniopsis, are mentioned as occurring in the Triassic, but these species probably in great part belong to other genera.

The Atremata, which contains the oldest and the simplest forms structurally, is represented by 29 genera, while the Neotremata and Protremata have 30 and 89, respectively. Telotremata is the last order to appear, and has by far the greatest number of genera, 179.

The chronogenetic history of brachiopods shows that the four orders begin with smooth shells, and that subsequently various kinds of surface ornamentation are developed or disappear with varying degrees of rapidity. The ontogeny of strongly plicated and lamellose shells, wherever observed, begins with smooth shells. All new surface characters

Digitized by Google

are first introduced during adolescent growth or senility, and these by the law of acceleration appear earlier and earlier in later species. In the Lower Cambrian there are species of Billingsella with a few broad undulations in the shell, but in the Middle Cambrian the plications are pronounced and cover half or more than half the anterior portion of the valves, while in the Upper Cambrian these folds appear upon the umbones. In the oldest rostrate pentameroids the shells are either smooth or have a few folds (Camarella), which become more distinct in Parastrophia, and culminate in numerous sharp plications in Anastrophia. The rhynchonelloids, beginning in Protorthis of the Lower Cambrian as smooth shells, gradually become more and more plicated in the Silurian and Devonian, yet in the Triassic many species again appear nearly smooth.

STRUCTURAL CHARACTERS.

THE PROTEGULUM.

The order Atremata is the radical brachiopodous stock, which early in its history gave origin more or less directly to the other three orders of brachiopods. Beecher has observed:[1]

> That all brachiopods, so far as studied by the writer, have a common form of embryonic shell, which may be termed the protegulum. The protegulum is semicircular or semielliptical in outline, with a straight or arcuate hinge line, and no hinge area. A slight posterior gaping is produced by the ventral valve being usually more convex than the brachial. The modifications noted are apparently due to accelerated growth, by which characters primarily nealogic [=neanic] become so advanced in the development of the individual as to be impressed finally upon the embryonic shell. This feature is well shown in the development of Orbiculoidea and Discinisca.
>
> As the protegulum has been observed in about 40 genera, representing nearly all the leading families of the class, its general presence may be safely assumed. [In structure it is corneous and imperforate and varies in size from 0.05 to 0.60mm. The] prototype preserving throughout its development the main features of the protegulum, and showing no separate or distinct stages of growth [is found in the Lower Cambrian genus Paterina]. The resemblance of this form to the protegulum of other brachiopods is very marked and significant, as it represents a mature type having only the common embryonal features of other genera.

Since the above was written Mr. C. D. Walcott has shown that the type species of Paterina has a well-developed cardinal area, and that it is synonymous with Iphidea.[2] The latter, however, is generally assumed to have an apical pedicle opening as in the Acrotretidæ. This is now known not to be the case. The supposed perforation is but a slight depression or short groove in the apex of the ventral valve, and does not pass through the shell. Iphidea is therefore in harmony with Paterina, since both have more or less well-developed cardinal areas. The theoretical Paterina or prototype of the protegulum is therefore

[1] Am. Jour. Sci., April, 1891, 3d series, Vol. XLI, pp. 344–346.
[2] Proc. U. S. Nat. Mus., Vol, XIX, 1897, pp. 707-713.

Digitized by Google

not yet known. It is evident, however, from the material Mr. Walcott possesses, that Iphidea-like forms will be discovered in which the cardinal area is undeveloped and in harmony with the protegulum. It is in this sense that the terms Paterina and paterina stage are used throughout this work.

THE PRODELTIDIUM.

The term prodeltidium is applied by Hall and Clarke to the third shell plate originating on the dorsal side of the body wall in the cephalula stage of *Thecidium mediterraneum*, the only living species of Protremata. This plate, however, is not restricted to that order, but has been observed by authors as also occurring in the Atremata and Neotremata. The term prodeltidium is here applied to this embryonic plate wherever it occurs unmodified.

Beecher has shown that the prodeltidium in the Protremata is the first cause for the development of the deltidium so characteristic of this order. That this plate is also present in the Neotremata is apparent from the description of a brachiopod larva of Discina (= Discinisca) given by Fritz Mueller. These larvæ were captured in abundance off Desterro or Santa Cathrina, Brazil, but Mueller was not so successful as Kovalevsky and others in securing the earlier larval stages of other genera developing in the brood pouch, and therefore nothing is known as to the place of origin of the prodeltidium in Neotremata. Since, however, the prodeltidium is also present in young Lingula of the order Atremata, where it is wholly attached to the interior of the dorsal shell, it appears safe to assume that this plate invariably develops on the dorsal side of the thoracic segment of embryonic brachiopods, and later becomes attached either to the dorsal (Atremata) or ventral valve (Neotremata and Protremata), except where, as in the Telotremata, it does not occur.

Before taking up the phylogenetic significance of the prodeltidium, it will be advisable to state what is known of this plate in the Atremata and Neotremata. Since it was first discovered by Fritz Mueller in the Neotremata, where also it is best developed, and subsequently was homologized by Brooks with a similar plate in Glottidia, it will here be given first consideration. Mueller writes:[1]

Mit ihrem Hinterrande dem ausgebuchteten Hinterrande des Bauchschale anliegend, gewahrt man zwischen den Schalen eine *querovale Platte*, 0.06 mm. lang, 0.11 breit, mit dunklerem, oft braunröthlich gefärbtem, ringförmigen Rande. Sie haftet an der Bauchschale, deren Bewegungen sie folgt, und steht mit der Rückenschale nur durch Muskeln in Verbindung.

There is, then, in this Discinisca, a transversely oval plate somewhat loosely attached to the ventral shell near its posterior margin, the movements of which it follows. Mueller adds:[2]

Die querovale Platte tritt unter des bis zum Vorderrande der Rückenschale vorgeschobenen Bauchschale vor, beginnt sich nach hinten zu verlangeren und ein faseriges Ansehen zu zeigen (Stiel?); sie folgt, nach wie vor, den Bewegungen der Bauchschale.

[1] Archiv Anat., Physiol., 1860, p. 74. [2] Ibid., p. 78.

Digitized by Google

Since in this stage of Discinisca there is no pedicle present, Mueller apparently was disposed to regard the prodeltidium as the equivalent of the pedicle. That this is an erroneous interpretation seems certain, for in his second paper he states:[1]

Die bis dahin zwischen den Schalen verborgene querovale Platte (der Stiel) tritt hervor, indem sie sich wie es scheint, um dem ausgebuchten Hinterrande des Bauchschale vollständig herumdreht und so ihr vorderer Rand zum hinteren wird.

In Glottidia the pedicle does not appear until sometime after the prodeltidium is developed, and it seems reasonable to assume from the description of Mueller that, on the development of the pedicle, the prodeltidium is pushed and turned backward, and between this and the notched ventral margin the pedicle passes. The pedicle opening at this stage is therefore surrounded by shell matter, anteriorly by the protegulum and posteriorly by the prodeltidium, characters duplicated in Thecidium. In the latter genus the prodeltidium develops into the deltidium, whereas, according to Mueller, this plate subsequently disappears in Discinisca. Brooks, also, is not disposed to accept Mueller's interpretation of this plate as the pedicle, since he writes:[2]

If it is the same [the transversely oval plate of Discinisca and the dorsal semicircular plate of Glottidia], Mueller is certainly in error in his suggestion that it is the pedunele, for there is no connection between the two structures.

In *Glottidia pyramidata*, Brooks has shown that the prodeltidium is also present, yet here it does not become attached to the ventral shell, but is firmly fastened to the dorsal valve, and this apparently was consummated in the paternia stage. Brooks writes:

I was not able to learn anything of the significance of the semicircular plate shown in figures 1 and 3. It is found only in the dorsal valve, and is either a mark upon its inner surface or a plate between the body and the valve. According to Fritz Mueller, the Brachiopod larva studied by him possessed a similar structure. * * * The embryo of Lingula is so small and thin that if this were a separate plate, it would be rather difficult to prove without seeing it move, or find it bent outward. In the absence of such evidence, we seem warranted in concluding that it is a similar structure to the movable plates of Mueller's larva, although, in Lingula at least, it is in connection with the dorsal, not the ventral valve.

No one has yet mentioned the presence of the prodeltidium in living Telotremata, and it may prove to be absent in this order, as it is not developed in the three species carefully studied by Morse, Kovalevesky, and Shipley.

Recapitulation.—The prodeltidium is present in Atremata, Neotremata, and Protremata. In the embryonic brachiopods developing this plate it is first found on the dorsal side of the body wall, and later is anchylosed to the ventral shell in Protremata (Thecidium). In the Neotremata, the earliest embryonic stages of which are not known, it is found completely developed and loosely attached to the ventral shell, anterior to the posterior margin. It subsequently turns backward to

[1] Archiv für Naturgesch., 1861, p. 54.

[2] Chesapeake Zoological Laboratory, session of 1878; Johns Hopkins University, 1879.

Digitized by Google

the posterior margin of the same valve, and the pedicle is believed to emerge between the plate and the valve (Discinisca). The prodeltidium is therefore alike in final position in the Neotremata and Protremata. In the Atremata this plate is either attached by its entire surface or by the posterior margin only to the dorsal shell, as in Glottidia, where the earliest embryonic stages are also unknown. The prodeltidium is likewise dorsal in the cephalula stage of Thecidium (Protremata), but subsequently is attached to the ventral shell, yet in reality remains dorsal to the animal. In Glottidia (Atremata) this plate remains attached to the dorsal valve, and in nowise affects the pedicle opening, as in the Neotremata and Protremata. In the Telotremata the prodeltidium has not been observed, nor has any fossil species in this order shown the least trace of a deltidium, and wherever the delthyrium is closed it is always by plates growing medially from its walls, secreted by the mantle and never by the peduncle. Therefore, when the prodeltidium remains stationary or with the dorsal valve, it is not known that this plate affects the original pedicle opening (Atremata and Telotremata), but when subsequently attached to the ventral valve and partly surrounds the pedicle with shell matter, it completely modifies the primitive pedicle opening by restricting it to the ventral shell (Neotremata and Protremata). In the derived or later-appearing families of the Neotremata and Protremata the effects of foraminal modification initiated by the prodeltidium may be wholly lost, as in Craniidæ and Orthiidæ.

SIGNIFICANCE OF THE PRODELTIDIUM.

The deltidium is the chief character of ordinal importance in the Protremata, and since this plate is attached to the ventral valve, yet originates in the dorsal prodeltidium, it seems reasonable to assume that if similar developmental conditions are found in other orders such orders would possess closer phylogenetic relationship than those having differing conditions. It has been shown that the prodeltidium is also attached to the ventral valve in the Neotremata, and so far both orders show relationship in their earliest embryonic growth. Beecher has shown that the protegulum or initial shell of the Protremata is discinoid in form and more like that of the Neotremata than that of the Atremata or Telotremata. He writes:[1]

> Discinisca shows a subcircular ventral protegulum with a pedicle notch, and the evidence of any hinge in the dorsal protegulum is very slight. The discinoid character appearing in the second and third nepionic stage of the Paleozoic Orbiculoidea has become so accelerated in Neozoic and recent Discinisca as to produce a discinoid protegulum.
>
> The strophomenoid shells usually retain a normal protegulum in the dorsal valve, but from the acceleration of the discinoid stage in the ventral valve the protegulum, has an abbreviate hinge and arcuate hinge line. (P. 346.)
>
> The nepionic stage of *Leptæna rhomboidalis* is represented by a shell without radii, having a comparatively large pedicle opening in the ventral valve and a large deltidium. The hinge is not well defined and the shell is discinoid in form. * * *

[1] Am. Jour. Sci., 3d series, Vol. XLI, 1891, p. 346; Vol. XLIV, 1892, pp. 150–151.

Digitized by Google

The external characters as expressed by both valves are manifestly nearer to Kutorgina than to any telotremate genus. * * * It should be noted, however, that the young of Chonetes, Productus, Stropheodonta, Orthothetes, Leptæna, Plectambonites, and Strophomena, all have little or no indication of a straight hinge line, and that the extension of this member takes place during later nealogic and ephebolic growth. (Pp. 150–151.)

By far the greatest number of Neotremata occurring in the Lower Cambrian are species of the family Acrotretidæ. To the writer it has always seemed strange to suppose that this family has been derived through the Trematidæ, but the above interpretation of the prodeltidium in Discinisca indicates that the turning of this plate posterior to the pedicle at once led to holoperipheral growth in some of these early forms. In some species of the Acrotretidæ there is a true deltidium. In Acrothele the cardinal area is flat, without any trace of a deltidium, whereas in Acrotreta and Conotreta, which have high cardinal areas, there is a narrow concave depression bisecting it. These deltidia, whether convex or concave, are in all probability initiated by the prodeltidium, as in the Protremata. In the family Trematidæ there appears to be nothing homologous with the deltidium, since the plates situated in the apex of the wide triangular fissure of Schizocrania and Lingulodiscina seem to be formed anterior to the pedicle and subsequent to its movement posteriorly with growth, and not posterior to the pedicle, as in the Acrotretidæ. These plates in the Trematidæ should probably be homologized with the listrium of the Discinidæ.

The complete harmony of the muscular system in the Protremata and Telotremata is no evidence in itself that the latter were derived from the former. The occurrence at the base of the Cambrian of very primitive species of the four brachiopod orders is proof that divergence took place very early in the history of the class, and while there is little knowledge of the muscles in either Iphidea, Kutorgina, or Protorhyncha (*P.? minor and P.? ambigua*), the earliest genera of Atremata, Protremata, and Telotremata, respectively, there is some evidence for supposing them to be as in the type embryo stage of living species. The high degree of specialization attained by Lingula (Atremata), as exemplified by the burrowing habit, long peduncle, and absence of valve articulation, is the cause for their complex muscular system, while the development of a functional hinge in the Protremata and Telotremata has led to the retention of very primitive conditions or to the simplification and harmony of the muscles throughout these two orders.

The presence of a terminal intestinal opening in the living species of the Atremata and Neotremata and its general absence in those of the Protremata and Telotremata is no longer held to have phylogenetic significance, as many of the Paleozoic species of the two latter orders afford good evidence of such having been present in the median line as in living Crania.[1]

[1] See p. 113.

Digitized by Google

The known protegula, or initial shells, of the Neotremata and Protremata have been shown to be harmonious, and to differ from the normal unmodified protegula of the Atremata and Telotremata. The paterina stage in the two last-named orders is followed by the "obolella stage" in the highest families of the Atremata (Lingulellidæ and Lingulidæ), and probably throughout the Telotremata, since it has been observed in a number of Ordovician and Silurian Rhynchonellacea, Spiriferacea, and recent Terebratulinas.[1] In the Neotremata and Protremata the paterina stage is not followed by the obolella stage, but usually by holoperipheral growth, except where the pedicle slit remains for a time wholly uninclosed by shell matter.[2]

In tabulated form the above-presented facts appear thus:

Table of fundamental brachiopod characters ordinally arranged.

Character.	Atremata.	Telotremata.	Neotremata.	Protremata.
1. Prodeltidium in type embryo.	With dorsal valve.	Absent	With ventral valve.	With ventral valve.
2. Prodeltidium affecting pedicle opening.	None	None	Modified in primitive forms.	Modified throughout.
3. Deltidium present	None	None	Present in primitive forms.	Present throughout.
4. Protegulum	Present	Present	Present	Present.
5. Obolella stage	Present	Present	Absent	Absent.
6. Anus	Present	In many early geologic species.	Present	Present in pentameroids.
7. Chemical nature of shell.	Phosphatic and calcareous.	Calcareous	Phosphatic and calcareous.	Calcareous.
8. Cardinal area	Present, but usually small.	Not generally present.	Present in primitive forms only.	Generally present.
9. Similarity of valves.	Very much alike.	Unlike.	Very unlike.	Unlike.
10. Articulation	Often present, not functional.	Functional	Rarely present, not functional.	Functional.
11. Nature and function of pedicle	Affixing and burrowing.	Generally present, affixing; shell rarely cemented.	Generally present, affixing; cementation complete.	Affixing or obsolete; cementation or anchoring spines present.
12. Brachia, with or without internal skeleton.	Without	With or without	Without.	With or without.

It now appears evident that the two great divisions of brachiopods heretofore based on the presence or absence of functional articulation have no phylogenetic significance, and as they "do not appear to have a primary developmental basis in nature, * * * they fail to express the true relationships of the various groups included in them."[3]

[1] See papers by Beecher and Clarke, Brooks, Morse, Beecher and Schuchert, and Winchell and Schuchert.

[2] See Am. Jour. Sci., 3d series, Vol. XLIV, 1891, pp. 150–151.

[3] Beecher, Am. Jour. Sci., 3d series, Vol. XLI, 1891, p. 353; also see Vol. XLIV, 1892.

Digitized by Google

Articulation was developed along two independent lines, and therefore the terms Lyopomata and Arthropomata have no phylogenetic significance. The presence or absence of articulating processes was at one time considered a fixed line, on either side of which all brachiopods could be arranged, but now articulation is known to be nearly functional in several lyopomatous genera, as in Spondylobolus, Trimerella, Monomorella, Tomasina, Barroisella, of the Atremata, and in Trematobolus of the Neotremata. Among the Arthropomata, articulation is hardly functional in Kutorgina, Schizopholis, Eichwaldia, and Dictyonella. However, it appears probable that two superorders exist, each having two orders. Atremata and Telotremata are the more primitive groups, and agree in the following fundamental characters: Prodeltidium attached to the dorsal valve or absent; pedicle opening primarily unmodified, and generally closed later by calcareous plates secreted by the ventral mantle extensions; presence of a functional pedicle throughout the life of the individual (except in Thecospira, Thecocyr-

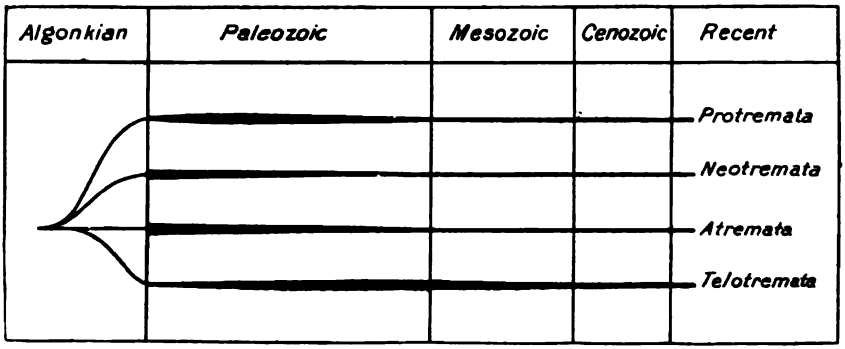


FIG. 1.—Diagram giving the geological distribution of brachiopod orders.

tella, and Bittnerula); general presence of the "obolella stage" in the ontogeny of atremate and telotremate species, and the development of complicated calcareous brachial supports in the derived order. The Neotremata and Protremata agree in having the prodeltidium attached to the ventral valve with complete nepionic modification of the pedicle opening; delthyrium often closed by a single plate secreted by the pedicle and never by mantle extensions; the pedicle is very often lost before maturity is attained, along with the development of new anchoring adaptations; absence of the "obolella stage" and complicated calcarious brachial supports.

Owen's superorders Lyopomata and Arthropomata have no basis in nature, and should be dropped. It is to be hoped that students will determine the complete embryology of Lingula, Discinisca, Crania, Rhynchonella, and Terebratulina, for until more of the ontogeny of some species of these genera is known, no satisfactory relationship which the orders bear to one another can be established. However, it appears probable that Atremata and Telotremata have superordinal relationship

Digitized by Google

differing from that of the Neotremata and Protremata. If the characters above pointed out are of superordinal value, it will be convenient to refer to these divisions as *Homocaulia* and *Idiocaulia*, respectively.[1]

DEVELOPMENT OF CARDINAL AREAS AND ARTICULATION.

The earliest suggestion of cardinal areas occurs in Iphidea of the Atremata and in the Acrotretidæ of the Neotremata. In none of these forms, however, is there a true cardinal area comparable with those of the Protremata and Telotremata, since it is not bisected by a delthyrium, nor are deltidial plates developed. A convex pseudodeltidium is often present, but this feature is not homologous with the deltidium of the higher forms. It is due to holoperipheral growth and interference by the pedicle. In the dorsal valves of primitive genera in both the Atremata and Neotremata growth is hemiperipheral, but in the ventral valve of Iphidea, the most primitive known genus of Atremata, and in the Acrotretidæ of the Neotremata, growth is holoperipheral.

The ontogeny of many species of Protremata shows that this order had its origin in some atrematous paterina-like genus. This must have occurred in pre-Cambrian times, since in the Lower Cambrian there are several species of Billingsella, a highly developed protrematous genus when compared with the theoretical Paterina. *Kutorgina cingulata* Walcott, also of the Lower Cambrian, is a more primitive species than any Billingsella, and it gives evidence as to the course of evolution from the inarticulate paterina-like ancestor to this rudimentary, articulate, long-hinged genus. *K. cingulata* in connection with the Indian genus Schizopholis Waagen shows that the opening between the widely gaping valves of Paterina, which was entirely occupied by the pedicle, was partially closed by a gradual thickening of the lateral walls, and there was slowly developed a primitive, ventral, cardinal area. This area and the articulating processes in *K. cingulata* are very rudimentary, and are situated at the lateral extremity of the cardinal area; thus this species still retains a very large open delthyrium, much as in the theoretical Paterina. In Schizopholis this wide fissure is reduced to a narrow triangular delthyrium by the development of a true cardinal area, and the articulating processes are now no longer at the lateral extremities, as in Kutorgina, but are situated more medially. Naturally, in the older Cambrian, complete articulation did not obtain, as in post-Cambrian times. Some of the oldest protrematous species, such as *K. cingulata*, *Billingsella whitfieldi*, and possibly others, also retain considerable phosphatic material in their shells, but in later and more highly specialized species the shell is decidedly calcareous.

Some of the species of Iphidea have the ventral posterior region

[1] Ὅμος (homos), ἴδιος (idios), and καυλός (kaulos) = stem or pedicle common to both valves and pedicle restricted to one valve, respectively. These characters may be retained throughout life or restricted to the neplonic and neanic stages of growth.

Digitized by Google

more drawn out beyond the dorsal posterior margin than others. If this rostrate condition were carried a little farther and the pseudodeltidium resorbed, there would practically result a telotremate shell duplicated by the neanic condition of many rostrate Telotremata. The articulation would at first be nearly obsolete and situated extremely lateral, as in the Protremata, but as the cardinal area became greater the teeth would attain a more medial position. While there are no known genera to fill in the gap between the theoretical Paterina and Protorhyncha (*P. minor and P. ambigua*), yet the hiatus between the Atremata and Telotremata is not greater than between theoretical Paterina and Kutorgina, or between the Atremata and Protremata.

DEVELOPMENT AND SIGNIFICANCE OF THE DELTIDIUM.

The most characteristic mature feature of ordinal importance which distinguishes Protremata from the other three orders is found in the plate that more or less completely covers the delthyrium. However, in two of the families of this order, Pentameridæ and Orthidæ, this plate is generally wanting in the mature individual, since here it usually develops only during early growth, and later is lost by abrasion or hidden beneath the incurved beak. Again, in the Acrotretidæ of the Neotremata, and in Iphidea of the Atremata, a deltidium-like plate is also often developed, but as these shells are strongly phosphatic it is not difficult to distinguish the ordinal position of any shells with a true deltidium. In *Lacazella mediterranea*, the only living species of Protremata, this plate has its origin in the cephalula stage along with the rudiments of the dorsal and ventral valves, when the embryo is yet free and swimming about by the aid of cilia. The dorsal shell and the prodeltidium appear first, and are secreted by the rudimentary dorsal mantle and the dorsal surface of the body, which subsequently becomes the pedicle. The ventral shell appears last, and is then widely separated from the dorsal valve. Between the two valves is the thick and short pedicle, on the dorsal surface of which still remains the third plate, or prodeltidium. Subsequently the latter is anchylosed to the posterior margin of the ventral valve. The prodeltidium is also known in the Atremata and Neotremata, yet in the Telotremata this embryonic third plate does not exist, but a covering to the delthyrium is developed sometime after the animal has become attached. In its origin this covering is wholly different from the deltidium of the Protremata, which has its beginning in the prodeltidium and grows down from the shell apex over the delthyrium, while the deltidial plates of Telotremata grow out medially from the walls of the delthyrium. The deltidial plates are secreted by extensions of the ventral mantle, and at no period of development has the pedicle any share in their formation. It is not always easy to distinguish mature protrematous and telotrematous shells on the basis of these characters alone, but the young of both orders are

Digitized by Google

easily classified by the covered or open delthyria, respectively. In some of the Telotremata, toward maturity the deltidial plates anchylose medially posterior to the pedicle, or they may surround the pedicle, thus resembling the deltidium, but, since their origin is quite different, they are termed "pseudodeltidia." Such pseudodeltidia in Cyrtia, Cyrtina, and some spirifers resemble the deltidium of Clitambonites. Even the median line of anchylosis is often obliterated by the continuous secretion of the completely united prolongations of the ventral mantle lobe. In the Pentameridæ the deltidium is generally absent, as in the Orthidæ, but in Pentamerus and Conchidium it is often retained as a thin, fragile, concave plate. This reversal in form from the generally prevalent, convex, or flat deltidium may be due to the rostrate and arched ventral umbones so common in these genera. In the aberrant rostrate genus Dictyonella, which has an arched ventral umbone, a concave plate is also present, between which and the shell the pedicle passes and emerges upon the umbone, as in the Siphonotretidæ. It is not certainly known that this plate in Dictyonella is a deltidium, but its form and position in the rostral cavity are very suggestive of that organ in Pentamerus and Conchidium. The peculiar umbonal pedicle opening in Dictyonella also finds its equivalent in Leptæna.

THE CHILIDIUM.

The chilidium is a convex plate often covering the cardinal process of the dorsal valve in the Protremata. It is particularly well developed in the families Clitambonitidæ and Strophomenidæ, and is not to be confounded with the deltidium, since it first makes its appearance not earlier than neanic growth, and apparently is a secretion of the dorsal mantle lobe. The origin of the chilidium and of the deltidium is therefore wholly different, and both have very dissimilar phyletic significance.

ORIGIN AND FUNCTION OF THE SPONDYLIUM.

The spondylium is an internal ventral plate traversing the posterior portion of the animal. The upper surface of this plate is usually transversely marked by striæ, which, in the Pentameracea have three distinct curvatures in passing over it.

Since their position and the area occupied agree with the muscular scars of this valve in *Orthis*, they are here regarded as homologous with the adductors, diductors, and adjustors of that genus. In *Lingulasma*, *Lingulops* and the trimerellids the muscular scars are not found in front nor underneath, but *on* the "platform" of those genera. The platform, therefore, is homologous with the spondylium of *Clitambonites* and *Pentamerus*. * * * The portion of the valve immediately beneath the spondylium, and occasionally the sides of the septum, are strongly marked by the genital sinuses. Since there is no space posterior to these markings for the attachment of the muscles, this clearly indicates that they were situated on the upper surface of the spondylium.[1]

[1] Winchell and Schuchert, Final Rept. Minn. Geol. Survey, Vol. III, Part I, June, 1893, p. 378.

Digitized by Google

The spondylium is developed as the "platform" in Lingulasmatidæ and Trimerellidæ of the Atremata; as a "spondylium" in Pentameracea of the Protremata, and in Cyrtina, Camerospira, Merista, and Dicamara, of the Telotremata. In the Atremata and Telotremata, spondylia-bearing species are not numerous, but the individuals are usually abundant, often of large size, and generally are of short geologic duration.

The development of the spondylium or its morphologic equivalent probably had its origin in an excessive deposit of testaceous matter about the bases of the powerful adductors, diductors, and pedicle muscles. Growth of the individual necessitates the progressive anterior movement of the muscles, and when these are large there is but little or no space left between or outside of them for the viscera and genitalia, which are therefore crowded farther and farther anteriorly. This condition naturally produces constant pressure of the genitalia against the anterior base of the forming spondylium, and since pressure causes resorption or diverts testaceous deposition, it follows that these organs will gradually produce cavities for their relief beneath this plate. In the older species of the Trimerellidæ and in all of the Lingulasmatidæ displacement of the genitalia does not appear to have been excessive, as the platforms are but slightly excavated. However, in the terminal genus Trimerella the genitalia chambers are very deep, and these are present in both valves. Throughout the Pentameracea the spondylium is a thin, freely terminating or medially supported plate, and never solid as in the older species of the Trimerellidæ. It is likewise thin and excavated in the order Telotremata.

Hall and Clarke advance quite a different explanation as to the origin of the spondylium. They write:[1]

> The *spondylium* is an area of muscular implantation. In its early or incipient condition it is evident that it originates from the convergence and coalescence of the dental lamellæ, and forms a receptacle for the proximal portion of the pedicle, and for the capsular or pedicle muscles. * * * Considering this structure in its incipent condition, where, as in *Orthis*, it is represented only by the convergent dental plates which usually unite with, or rest upon the bottom of the valve, and inclose only the base of the pedicle and its muscles, it will be evident that the plate is actually but a modification of the original pedicle-sheath. It is evidently the inner moiety of this sheath surrounding the pedicle, which has become involved or inclosed by the growth of the pedicle-valve, and further modified by the development of articulating processes where it comes in contact with the brachial valve It therefore follows, as a natural inference, that wherever the spondylium is present, whether in the incipient condition or in the more advanced stage of development in which it supports all the muscles of the valve, it is, or, at some period of growth, has been accompanied by the *external* portion of the sheath, which is termed the deltidium. Thus the spondylium appears to be but the complement of the deltidium, or the original plate formed upon the body of the embryo, and that portion of the adult shell to which the term deltidium has been applied, is the other part of the original or primitive deltidial plate or pedicle-sheath.

[1] Palæontology of New York, Vol. VIII, Part II, 1895, p. 332.

Digitized by Google

The writer also previously entertained this view, but when it became known that spondylia are developed where no dental lamellæ exist, as in the Lingulasmatidæ and Trimerellidæ of the Atremata; that spondylia are never present in the Neotremata, where a pedicle-sheath is sometimes well developed, as in the Acrotretidæ; and finally, that a spondylium is even present where no deltidium ever existed, as in the two first-mentioned families, and in Cyrtina, Camerospira, Merista, and Dicamara of the Telotremata, such an explanation became untenable. The fact that solid or excavated spondylia exist in three orders, two of which never developed a pedicle-sheath (Atremata and Telotremata), and one had no dental lamellæ (Atremata), is good evidence that the prodeltidium primarily had nothing to do with the development of spondylia. Further, no spondylia are developed in the Cambrian until long after the deltidium was well established, and therefore the spondylium can not be "but a modification of the original pedicle-sheath." However, it is very probable that when the dental lamellæ in the Protremata became sufficiently wide to join the ventral shell, crowding all the muscles of this valve into a small area, these took advantage of the inner sides of the dental lamellæ for insertion, and thus a continuous layer of testaceous matter was deposited within the rostral cavity. With growth, the muscles move forward and press against the genitalia, which causes resorption or nondeposition for their relief. No spondylia appear before the Upper Cambrian, and here also are the first completely developed dental lamellæ. The so-called Lower Cambrian camarellas have no completely developed dental lamellæ, and are related to the rhynchonelloid genus Protorhyncha, and to *Protorthis billingsi*, which also has no spondylium.[1] Therefore, the further conclusion of Hall and Clarke can not be accepted, that, "where the teeth are wholly without dental lamellæ, or where such lamellæ do not extend to the bottom of the valve, it seems necessary to regard them as instances of degeneracy or resorption of the primitive spondylium."[2]

It seems clear to the writer that since the "shoe-lifter" plate, or spondylium, in Merista and Dicamara is for muscular insertion, this plate in the ventral valve of these genera is the morphic equivalent of the spondylium in the Pentameracea, and that the dorsal muscular plate in Dicamara is the equivalent of the cruralium, and can not "be interpreted as an entirely different structure from the spondylium."[3] It is true that the spondylia of these genera are not exactly like those of the Pentameracea, but since this plate in the Atremata is not formed by the union of dental lamellæ, as these do not exist in this order, there is no reason for rejecting the terminology for these plates in Merista and Dicamara.

[1] *Camarella minor* and *C. antiqua* are more closely related to Protorhyncha than to any other genus. Of *Orthis billingsi*, the type of Protorthis, very good casts of specimens in the Cornell University Museum are in the National Museum, which show that this genus also has no spondylium, and that its characters are those of Billingsella.

[2] Hall and Clarke, ibid., p. 333.

[3] Ibid., p. 335.

Digitized by Google

CRURA AND CRURALIUM.

Calcareous processes for the support of the brachia are also developed in the Protremata, in the superfamily Pentameracea, but never to the same degree attained by the Spiriferacea or Terebratulacea of the Telotremata. In the Protremata these supports are first developed in the Syntrophiidæ, and attain their greatest length in the Pentameridæ. Since the two parts often unite medially, forming a plate for muscular insertion either resting upon the valve or supported by a septum, this has been termed a cruralium by Hall and Clarke, to distinguish it from the spondylium of the ventral valve. When the parts remain separate, and are therefore not for muscular insertion, they are homologous with and the equivalent of the crura in the Rhynchonellidæ. The crura of the Pentameracea and Rhynchonellacea arise independently, and are therefore morphologic equivalents.

MORPHOLOGIC EQUIVALENTS.

Because of the presence of similar or identical morphological structures in different groups of mature brachiopods, it is unsafe, on the basis of these alone, to suppose such to have close relationship. The spondylium has been shown to originate independently in three orders: Atremata, Protremata, and Telotremata. Identical mature loops have resulted in different ways in two stocks of the same family, one boreal (Dallinæ) and the other austral (Magellaninæ). Flat and more or less wide cardinal areas develop independently of one another in Protremata and Telotremata (Spiriferacea). Cementation of valves takes place at different and widely separated geologic epochs in Neotremata, Protremata, and Telotremata, and shell plications arise from smooth stocks in Pentameracea, Rhynchonellacea, Spiriferacea, and Terebratulacea. Natural phylogenies can only be established upon ontogenies checked by chronogenesis or geologic succession.

SUMMARY.

In North America there are 1,859 Paleozoic, 49 Mesozoic, and 14 Cenozoic species of fossil Brachiopoda. There are 116 species in the Cambrian, 319 in the Ordovician, 311 in the Silurian, 663 in the Devonian, and 478 in the Carboniferous.

The remarkable scarcity of post-Paleozoic species in America is supposed to be due not so much to the general decline of the class as to great orographic movements during the close of the Paleozoic, which produced complete barriers against the introduction of species from other areas.

Specific differentiation was most rapid in the Ordovician, having exceeded the Cambrian representation more than three times.

Thirty per cent of all American Paleozoic species had wide geographic distribution, which is most pronounced in the Devonian and

Digitized by Google

Carboniferous systems. One hundred and twenty-one American species are also found on other continents.

Widely dispersed species are least common in the most primitive order, Atremata, and greatest in the highest orders, Protremata and Telotremata. The difference, however, is but 7 per cent.

The order Atremata is represented by 199 species, or over 10 per cent of the American Paleozoic representation. In the Neotremata it is 156, or over 8 per cent. The Protremata have 738 species, or nearly 40 per cent; and the Telotremata 766 species, or about 41 per cent.

The order Atremata is best developed in species and genera in the Cambrian and Ordovician systems; the Neotremata in the Ordovician; the Protremata in the Ordovician, Silurian, and Devonian; and the Telotremata in the Devonian. The climax of differentiation is therefore chronologically related to phylogenetic or sequential origin.

Since the four orders of Brachiopoda are present in the Lower Cambrian, ordinal differentiation must have taken place in pre-Cambrian times. The two more primitive orders, Atremata and Neotremata, have in Lingula and Crania, respectively, genera with longest life histories. This probably is due not so much to their primitive structures as to their modes of living.

The last order to originate, Telotremata, has the greatest number of generic and superfamily characters, and probably also of species.

The last superfamily to appear, Spiriferacea, manifests most rapid evolution and is the second one to die out, being preceded by the Pentameracea. These two superfamilies are the most highly specialized in the orders to which they belong, and their great specialization may be the cause of their early disappearance.

The trunk families of later origin throughout the class manifest the greatest specific and generic differentiation and the widest specific dispersion, and have species of the largest size and often of longer geologic persistence.

The oldest or most primitive families nearly always have short geologic duration (except Rhynchonellidæ) and the least generic and specific differentiation, and commonly the individuals are of small size.

The largest of all brachiopods occur in the families Pentameridæ, Productidæ, and Spiriferidæ, at a time when the class was at the height of differentiation.

Large specific size is probably often gradually attained in genetic lines, and is due to favorable food conditions. The gigantic brachiopods always occur in the later-developed trunk families, and just before their decline in differentiation.

But 8 genera are known to pass from the Paleozoic to the Mesozoic. There are in all 327 brachiopod genera, 227 of which are Paleozoic. The Atremata have 29 genera, the Neotremata 30, the Protremata 89, and the Telotremata 179.

All brachiopods begin with smooth shells and protegula.

Digitized by Google

The prodeltidium, or third embryonic shell plate, is known in the Atremata, Neotremata, and Protremata. In the Atremata this becomes attached to the dorsal valve, while in the Telotremata it is apparently not developed at all. In the Protremata it becomes attached to the ventral valve, as in Neotremata. In the two last-named orders it modifies the pedicle opening. For this and other ontogentic and morphologic characters, Owen's terms Lyopomata and Arthropomata are abandoned. The Atremata and Telotremata are provisionally arranged under the superordinal term *Homocaulia*, and the Neotremata and Protremata under *Idiocaulia*.

Morphologic equivalents, or similar structural features, are developed independently, as follows: A spondylium in Obolacea, Lingulacea, Pentameracea, and rarely in Spiriferacea; crural processes in Pentameracea and Rhynchonellacea; functional articulation in Protremata and Telotremata; straight, more or less long, cardinal areas from rostrate forms in Rhynchonellacea, Spiriferacea, and Terebratulacea; rostrate shells from long cardinal areas in Pentameracea, and loss of pedicle and ventral shell cementation in Craniacea, Strophomenacea, and Spiriferacea.

Digitized by Google

CHAPTER IV.

MORPHOLOGY OF THE BRACHIA.

By CHARLES E. BEECHER.[1]

The diagnostic value of the brachidium, or calcareous arm supports, of brachiopods has long been recognized, and forms one of the chief characters for generic and family subdivision among the Terebratulacea and Spiriferacea. This character fails in all other brachiopods, which have simply fleshy arms, unsupported by calcareous skeletons. There is, however, generally the most obvious analogy and intimate relationship between the arms themselves and the brachidium, so that whenever either structure can be ascertained it furnishes important data aiding in the determination of the systematic position of any genus within a family or order.

The growth of the arms, or lophophore, in recent genera may be divided into distinct stages, which often have a direct correlation with other important features of the shell. In many cases it is also possible to infer the form and arrangement of the brachia in fossil genera from markings on the interior of the valves and from the calcareous arm supports, and thus to obtain the chronogenetic as well as the morphogenetic history of these organs.

The most detailed accounts of arm development are given by Brooks[5] for Glottidia, by Morse[11] for Terebratulina, and by Kovalevski[10] for Cistella and Thecidea. These results, combined with original observations by the writer[1,2] and occasional descriptions of arm structure by Davidson[7] and other authors, are sufficient to include and properly interpret all the leading varieties of structure.

As shown by Brooks,[5] the tentacles, or cirri, in Glottidia originate on the dorsal side of the oral disk. They grow in pairs, one on each side of a central lobe. New tentacles are added between the first pair formed and the median lobe. Thus the cirri farthest removed from the median lobe are the oldest. Tentacles are added rapidly until the first arc is extended to a semicircle, and then progressively the whole disk becomes surrounded by a circle of these organs. The further introduction of cirri can only take place by the enlargement of the oral disk or through the deformation of the circle by lobes, loops, or extensions. In Glottidia, Lingula, Discinisca, Crania, and Rhynchonella the two points of tentacular increase, originally together and on

[1] The references to the literature will be found at the end of this chapter.

Digitized by Google

opposite sides of a median lobe, or tentacle, gradually separate, and the further multiplication of tentacles results in strap-shaped extensions on each side, which finally assume a coiled form, due to the limited space in which they grow. Therefore the arms in adult individuals of these genera have a single cirrated edge, extending from their free extremities to the sides of the oral disk, and, continuing posteriorly, unite on the ventral side of the disk behind the mouth. Each cirrated edge in the adult lophophore apparently has two approximate rows of alternating cirri (Hancock[9]), but as they were originally a single row in early stages, this appearance is evidently the result of a crowding of the cirri or a crumpling of the edge.

Kovalevski[10] has shown that in Cistella the tentacles also originate in pairs on each side of the dorso-median line, without a central tentacle or lobe. The same mode of increase has been shown by the writer[2] to be present in Magellania and Terebratalia. In young stages of Cistella, Terebratulina, Magellania, and other terebratuloid genera, as well as in Thecidea, after the circlet of tentacles is complete the two points at which new ones are added do not separate, but remain close together throughout the life of the animal. In this case the cirrated margin is lengthened by means of lobation and looping, and often by the final growth of a single, median, coiled arm, cirrated on both margins. Gwynia illustrates the completed circle of tentacles about the mouth. Adult Cistella shows an advance in having the anterior margin of the lophophore introverted, making it bilobed. Megathyris is slightly more complicated by two additional lobes. This simple method of increase is further elaborated in the Thecidiidæ. In the higher genera, especially among the Terebratulidæ, the maximum is reached by means of a median, unpaired, coiled arm, as in Magellania and Terebratulina.

The development of the different types and varieties of arm structure is presented in the accompanying figures (figs. 2–6), which are necessarily somewhat diagrammatic in order to show the features clearly, but the essential structure can readily be verified from consultation of the works cited or from a study of actual specimens. In the case of fossil forms, such as Dielasma, the Atrypidæ, and Athyridæ, the brachial supports have sufficient analogy with the arm structures of Terebratulina and Rhynchonella to warrant their interpretation as given. Also the spiral impressions on the valves of Davidsonia, and those occasionally present in Leptæna and Productus, clearly point to the possession of coiled arms by these genera.

CLASSIFICATION OF BRACHIAL STRUCTURES.

From what has already been shown it is seen that the various types of lophophores admit of a simple classification into stages and groups. It is proposed to give to these distinctive names, which may be used with facility in making comparisons and correlations. They may be found

Digitized by Google

useful, also, in designating the kind of brachial complexity attained in any genus the arm structure of which can be determined, thus helping to fix its place in a genetic scale. It should be emphasized, however, that the form and complexity of the cirrated margin of the lophophore can have a taxonomic value only within comparatively narrow limits. This at once becomes evident when the arms of Lingula, Discinisca, Crania, Rhynchonella, and all the Spiriferacea are considered. Each has spiral arms, which were probably developed through similar changes of form, and yet each is genetically distinct, as shown by all the other leading characters. But when this classification of arm structures is applied within a family or genus, or even when made the basis of comparison among some closely related families, it is sometimes possible to reach very satisfactory conclusions relating to the systematic position of various forms.

LEIOLOPHUS STAGE.

It is hardly necessary to direct attention to the embryonic brachial structure before the growth of any of the tentacles, or cirri, on the edge of the lophophore, while the animal is in the typembryonic stage. For the sake of designating all the stages, this may be called the *leiolophus* stage, though it has no special significance beyond indicating the beginning of the lophophore.

TAXOLOPHUS STAGE.

The first stage in which a true brachial structure is manifest is an early larval form, often the protegulum stage, when the tentacular portion of the lophophore is a simple arc, or crescent. This may be called the *taxolophus*. The tentacles are few in number, and increase takes place on each side of the median line, dorsally, in front of the mouth. In figs. 2*a*, *e*, 3*a*, *f*, 5*a* this character is clearly shown. The tentacles at the ends of the arc are the oldest, and new ones are being formed in the middle portion. In Thecidea, Cistella, and Magellania the tentacles of the taxolophus are centripetal, due to the edge of the lophophore being near the margin of the shell; while in Terebratulina, Discinisca, and Lingula they are centrifugal, due to the smaller and central lophophore.

So far as known, there is no adult living form which has the taxolophian brachial structure. It may have been present in adult Iphidea of the Cambrian.

TROCHOLOPHUS STAGE.

By the continual addition of new cirri and the pushing back of the old ones, the fringed margin of the lophophore passes from a crescentic to a circular form, thus making a complete ring about the mouth. This may be termed the *trocholophus* stage. It appears in the late larval and early adolescent stages of Thecidea (fig. 2*b*), Cistella (fig. 2*f*), Magellania and Terebratalia (fig. 3*b*), Terebratulina (fig. 3*g*), Glottidia (fig. 5*b*),

Digitized by Google

and Discinisca, and, like the former stages, is undoubtedly common to all brachiopods, except, perhaps, Iphidea.

Gwynia is an adult living representative of this stage, and never develops any higher type of brachial structure. Dyscolia also belongs here, since it has a discoid lophophore surrounded by a marginal fringe of tentacles (Fischer and Œhlert[8]). It is possibly a little more advanced than Gwynia, as it has a slight median anterior notch, suggesting the beginning of the bilobed structure of the next higher type.

The absence of septum, hinge-plate, and dental plates are other primitive characters belonging to Dyscolia.

SCHIZOLOPHUS STAGE.

After the completion of the trocholophus stage in all brachiopods, except such simple forms as Gwynia and Discolia, no further increase in the cirrated edge of the lophophore can occur without some deformation of the circle. This is first accomplished by an introversion of the anterior median edge, thus dividing the lophophore into two lobes, and suggesting the name *schizolophus* for this type. (See figs. 2*c*, *g*, 3*c*, *h*, 5*c*.)

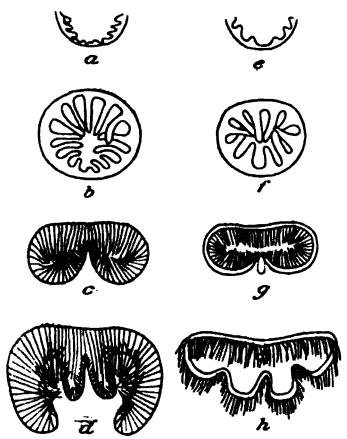


FIG. 2.—Stages of growth of the lophophore in Thecidea, Cistella, and Megathyris. *a*, *b*, *c*, *d*, stages in the growth of the lophophore in *Thecidea* (*Lacazella*) *mediterranea*, enl. (*a*–*c* after Kovalevski, *d*, after Lacaze-Duthiers). *e*, *f*, early stages of lophophore of *Cistella neapolitana*, enl. (after Kovalevski). *g*, adult lophophore of Cistella (*C. cistellula*), enl. (after Davidson). *h*, labial appendages of *Megathyris decollata*, enl. (after Davidson).

Several brachiopods retain the schizolophian brachia as an adult character. Of these, Cistella is perhaps the best example, as it agrees exactly with an early stage of arm structure among the Terebratellidæ, which has been called the cistelliform stage (fig. 3*c*). Terebratulina (fig. 3*h*), Glottidia (fig. 5*c*), and other higher forms, also have corresponding schizolophian stages, but are without the median septum. *Lacazella mediterranea* presents a similar larval structure, and in *L. barretti* it is retained to maturity. The fossil genera Davidsonella and Thecidella of the Thecidiidæ, and Zellania of the Terebratellidæ, never developed beyond the schizolophus stage, and they must therefore be considered as quite primitive genera in their respective families.

From this point the further development and complication of arm structure proceeds in three distinct diverging lines, producing the

Digitized by Google

three characteristic types of brachia of all the higher brachiopods, as exemplified in Thecidea, Terebratulina, and Rhynchonella.

PTYCHOLOPHUS STAGE.

The simplest of the types of brachia just cited is developed out of the schizolophus by the additional lobation, or looping, of the primary lobes, making a structure which may be called the *ptycholophus*. Megathyris and *Lacazella mediterranea* both have 4 lobes (fig. 2*d*, *h*); *Thecidea radiata* has 6; *T. vermicularis* and *Eudesella mayale*, 8; *E. digitata*, 10; Pterophloios and Oldhamina, about 20. Lobation in some (Thecidea) is produced by the forking or branching of the median septum; in others (Pterophloios) the septum remains simple while the lateral borders of the lophophore are lobed.

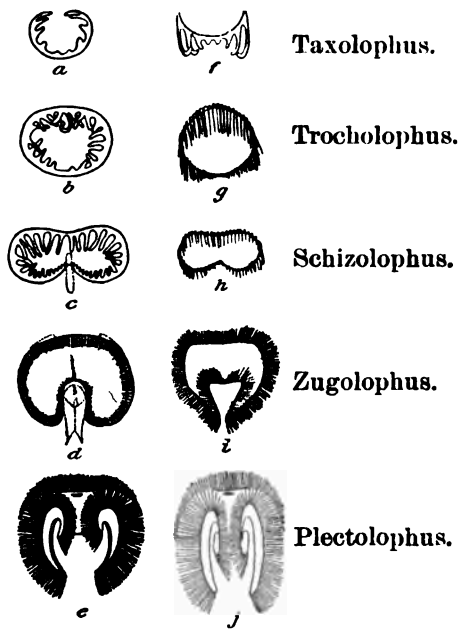


FIG. 3.—Stages of growth of the lophophore in the Terebratellidæ and Terebratulidæ. *a*, *b*, *c*, *d*, *e*, five stages in the development of the lophophore in the Terebratellidæ. *a–d*, *Terebratalia obsoleta*, enl. (after Beecher[2]). *e*, *Magellania kerguelenensis*, nat. size (after Davidson[7]). *f*, *g*, *h*, *i*, *j*, development of lophophore in the Terebratulidæ. *f–i*, early stages in *Terebratulina septentrionalis*, enl. (after Morse[11]). *j*, adult *Terebratulina cancellata* (after Davidson[7]).

ZUGOLOPHUS AND PLECTOLOPHUS STAGES.

All the higher Terebratulacea reach the final growth of the lophophore through an intermediate stage which from its form may be called the *Zugolophus*—fig. 3*d*, *i*. Eucalathis and Platidia (?Tropidoleptus) are apparently adult representatives of this stage, while Kraussina and probably Bouchardia are slightly more advanced by the growth of a short median, coiled arm, and lead to the next highest, or plectolophus, stage, in which there is a well-developed spiral arm with a fringe of cirri on each edge—fig. 3*e*, *j*.

A long loop pointed in front like Rensselæria and Centronella could not have supported a median arm, as the pallial cavity is thus fully occupied, and the development of the brachidium in the Terebratellidæ shows that the central space between the branches of the loop is to accommodate such an organ. The same is doubtless true of Dielasma, which first has a Centronella-like loop, and through the subsequent resorption of the anterior portion the ascending branches are formed

Digitized by Google

and space allowed for the median arm—fig. 4*a–d*. In a spire-bearing genus like Zygospira this is more obvious, for here the transverse process or jugum is clearly the result of the growth and resorption of the centronelliform loop to admit the spiralia.

FIG. 4.—Metamorphoses of the brachidium in *Dielasma turgida*, enl. (after Beecher and Schuchert).

The calcareous loop in Terebratulina and Liothyrina is only a posterior basal support, and does not repeat the outline of the cirrated margin of the lophophore, exclusive of the arm. Therefore it is impossible in these and closely allied genera to infer the stage of development of the lophophore from the loop alone. Dyscolia is an excellent example, since the loop is the same as in Terebratulina; but the lophophores are quite distinct in each, the former being of the trocholophus type and the latter belonging to the plectolophus.

SPIROLOPHUS STAGE.

The last type to be noticed is the one in which there are two separate coiled arms, each with a row of cirri on one edge only—fig. 5*d*, *e*. It embraces the greater part of the families of brachiopods in the orders Telotremata and Protremata, and includes all the living species in the orders Atremata and Neotremata.

In the early stages of development of the spiral lophophore there is an agreement with the early stages of the families already noticed, and the taxolophus, trocholophus, and schizolophus stages may be determined—fig. 5*a*, *b*, *c*. The separation and growth of the spiral arms seem to be due to the widening or expansion of the median lobe or tentacle, on each side of which is the formative tissue for new cirri. This is very apparent in the young Discinisca described by Muller,[12] and the Glottidia described by Brooks.[5]

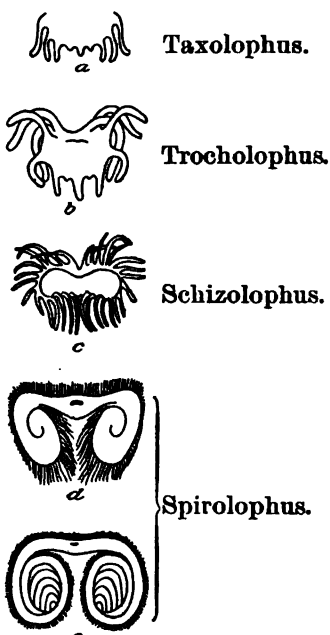


FIG. 5.—Early stages of lophophore of Glottidia and adult brachia in Lingula and Hemithyris. *a*, *b*, *c*, early stages of lophophore of *Glottidia audebarti*, enl. (after Brooks). *d*, adult brachia in Lingula (after Woodward). *e*, adult brachia in *Hemithyris psittacea* (after Hancock).

The brachidium in Zygospira passes through a series of changes which have been described in detail elsewhere.[4] These metamorphoses are of great assistance in understanding the development and comparative morphology of this feature in other groups of the Spiriferacea. The earliest stage observed (fig. 6*a*) has the form of a simple terebratuloid loop, which, from its resemblance to Centronella, was called the

Digitized by Google

centronelliform stage. Since approximately this form of brachidium is also characteristic of the young of recent terebraluloids, it may be taken in Zygospira as indicative of the trocholophus stage of brachial development. With this as a starting point for comparison, the further correlation of the succeeding stages is very simple.

The first resorption of the end of the loop in Zygospira produced a schizolophus condition, and further resorption carried the brachidium to a stage closely resembling Dielasma (fig. 6*b*). The dielasmatiform stage has already been explained as due to the requirements of space for the growth of the coiled brachia. Next, the initial calcification of the spiral arms resulted in the extension of the descending branches beyond the jugum (fig. 6*c*), and, lastly, complete calcification manifests the spirolophus structure and produced the characteristic brachidium of the Spiriferacea.

The Atrypidæ and the Athyridæ seem to stand to each other in the same relation as the Terebratellidæ and Terebratulidæ. In the first the descending branches are widely separated and follow the edges of the valves; in the second the descending branches are close together. This difference in the Spiriferacea produces the converging cones of the Atrypidæ (fig. 6*d*) and the diverging cones of the Athyridæ, Spiriferidæ, Retziidæ (fig. 6*e*), etc.

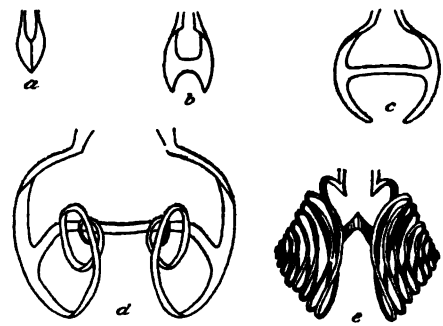


FIG. 6.—Metamorphoses of brachidium of Zygospira and adult brachidium of Rhynchospira. *a*, *b*, *c*, *d*, metamorphoses of brachidium of *Zygospira recurvirostra*, enl. (after Beecher and Schuchert). *e*, Brachidium of *Rhynchospira evax* (after Beecher and Clarke).

It seems doubtful whether the fleshy portions of the brachia in the Meristellidæ and Athyridæ possessed additional characters expressing the complexity and elaboration reached by the jugal processes, even when the lamellæ were duplicated, as in Koninckina and Kayseria.

From the above descriptions and illustrations it appears that the mode of growth of the cirrated lophophore, or brachia, is alike in the larval stages of all brachiopods. They first develop tentacles in pairs on each side of the median line in front of the mouth (taxolophus stage). New tentacles are continually added at the same points, until, by pushing back the older ones, they form a complete circle about the mouth (trocholophus stage), later becoming introverted in front (schizolophus stage). From this common and simple structure all the higher types of brachial complication are developed through one of two methods: (1) The growing points of the lophophore, or points at which new tentacles are formed, remain in juxtaposition; or (2) they separate. Complexity in the first is produced (*a*) by lobation, as in

Digitized by Google

Megathyris, Eudesella, Pterophloios, Thecidea, etc. (ptycholophus type), and (*b*) by looping (zugolophus) and the growth of a median, unpaired coiled arm (plectolophus), as in Magellania, Terebratulina, etc.; in the second (*c*) by the growth of two, separate, coiled extensions or arms, one on each side of the median line (spirolophus), as in Lingula, Crania, Discinisca, Rhynchonella, Leptæna, Davidsonia, Spirifer, Athyris, Atrypa, etc.

REFERENCES.

1. Beecher, C. E., 1893: Revision of the families of loop-bearing Brachiopoda. Trans. Conn. Acad., Vol. IX.

2. Beecher, C. E., 1893: The development of *Terebratalia obsoleta* Dall. Trans. Conn. Acad., Vol. IX.

3. Beecher, C. E., and J. M. Clarke, 1889: The development of some Silurian Brachiopoda. Mem. N. Y. State Museum, Vol. I, No. 1.

4. Beecher, C. E., and Charles Schuchert, 1893: Development of the brachial supports in Dielasma and Zygospira. Proc. Biological Soc. Washington, Vol. VIII.

5. Brooks, W. K., 1879: The development of Lingula and the systematic position of the Brachiopoda. Johns Hopkins Univ., Chesapeake Zool. Lab.

6. Davidson, T., 1851–1885: A monograph of the British fossil Brachiopoda. Pal. Soc.

7. Davidson, T., 1886–1888: A monograph of recent Brachiopoda. Trans. Linn. Soc., London, Vol. IV.

8. Fischer P., and D.-P. Œhlert, 1892: Résultats des campagnes scientifiques accomplies sur son yacht par Albert 1er, Prince Souverain de Monaco. Fs. III, Brachiopodes de l'Atlantique Nord.

9. Hancock, A., 1858: On the organization of the Brachiopoda. Phil. Trans., Vol. CXLVIII.

10. Kovalevski, A. O., 1874: Observations on the development of Brachiopoda. Proc. Imp. Soc. Amateur Naturalists, etc., held at the University of Moscow, 11th year, Vol. XIV.

11. Morse, E. S., 1873: On the early stages of *Terebratulina septentrionalis* (Couthouy). Mem. Boston Soc. Nat. Hist., Vol. II.

12. Müller, F., 1860: Beschreibung einer Brachiopodenlarve. Archiv Anat. Physiol., Jahrg. 1860.

Digitized by Google

CHAPTER V.

CLASSIFICATION OF THE BRACHIOPODA.

HISTORICAL.

Fabius Columna, in 1616, and Martin Lister, in 1678, were the first to describe brachiopods, calling them *Conchæ anomiæ*. Grundler, in 1774, was, however, the first to give a good illustration of a brachiopod in *Terebratulina caput-serpentis*. In 1818 Lamarck recognized 5 genera, including the operculate coral Calceola. Other genera were added by Sowerby, Dalman, and Defrance, from 1820 to 1830, and in the early forties about 1,500 species had been defined. In 1849 King recognized 49 genera in 16 families, and Bronn, in 1862, knew nearly 2,000 species and 51 genera. At present there are probably no fewer than 6,000 species known in 321 genera, grouped in 31 families, 9 superfamiles, 4 orders, and 2 superorders.

Since 1858 the class Brachiopoda has been divided by nearly all systematists into two orders, based on the presence or absence of articulating processes. These two divisions were recognized by Deshayes as early as 1835, but not until twenty-three years later were the names Lyopomata and Arthropomata given to them by Owen. These terms have been generally adopted by authors, though some prefer Inarticulata and Articulata of Huxley, or Bronn's Ecardines and Testicardines. Bronn, in 1862, and King, in 1873, while retaining these divisions, considered the presence or absence of an anal opening more important than articulation, and accordingly proposed the terms Pleuropygia and Apygia, and Trententerata and Clistenterata, respectively. In many Paleozoic genera of Clistenterata it has been shown that an anal opening was also present, and therefore the absence or presence of this organ is not of superordinal value. Beecher writes:[1]

> The dorsal beaks of Amphigenia, Athyris, Cleiothyris, Atrypa, and Rhynchonella are usually notched or perforate. The perforation comes from the union of the crural plates above the floor of the beak leaving a passage through to the apex. A similar opening occurs between the cardinal processes in Strophomena, Stropheodonta, and allied genera, and the chilidium may also be furrowed, as in *Leptæna rhomboidalis*. This character is evidently in no way connected with the pedicle opening, but points to the existence, in the early articulate genera, of an anal opening dorsal to the axial line, as in the recent Crania. This dorsal foramen was described and figured by King

[1] Am. Jour. Sci., 3d series, Vol. XLIV, 1892, p. 147. See also King, A Monograph of the Permian Fossils of England, 1850; and Œhlert, Fischer's Manuel de Conchyliologie, Appendice, 1887.

Digitized by Google

in 1850, Hall in 1860, and by several authors since, and has commonly been termed a visceral foramen. Œhlert suggests that it was probably occupied by the terminal portion of the intestine. The persistence of the foramen seems to indicate an anal opening.

Hall and Clarke state:[1]

It has become evident, from a study of the hinge plate, that the so-called visceral foramen which perforates it, and which is often present in Athyris, Rensselæria, Cryptonella, etc., is a remnant of this aperture, the remainder of the median opening having become filled by a testaceous secretion. There is every reason to believe that the visceral foramen was actually traversed by the lower alimentary canal, and if this were true, then the deep and narrow median chamber bounded by the crural plates must also have inclosed the terminal portion of the intestine.

In 1834 Von Buch also divided the class into two sections, founded on the mode of attachment. The first section contained all brachiopods fixed by a pedicle to foreign bodies, while the second was restricted to those forms in which there is no pedicle at maturity, the entire lower or ventral valve being cemented to other objects, as in Crania. The first section was again divided into three groups, on the basis of the pedicle: (*a*) Pedicle emerging from between the valves, as in Lingula; (*b*) ventral valve perforated for the protrusion of the pedicle; and (*c*) uncemented shells without a pedicle opening. The third group, however, is identical with *b*, since Leptæna, Productus, and Strophomena, genera referred to section *c*, do possess a pedicle opening. While this classification lacks a complete understanding of the features in question, it is remarkable that Von Buch nearly sixty years ago, and Deslongchamps twenty-eight years later, recognized some of the principles upon which the classification of the Brachiopoda is now established, viz, the nature of the pedicle opening.

Up to 1846 the general external features of brachiopods served the majority of authors as the essential basis for generic differentiation. In that year, however, King pointed out that more fundamental and constant characters exist in the interior of the shell, a fact which soon came to be generally recognized, mainly through the voluminous writings of Thomas Davidson.

In 1848 Gray, probably stimulated by King's paper, divided the Brachiopoda into two subclasses, Ancylopoda and Helictopoda. These divisions rest entirely on the basis of the structure and the presence or absence of calcareous supports. The Ancylopoda are distinguished in having the "oral arms recurved and affixed to fixed appendages on the disk of the ventral [dorsal] valve," while in Helictopoda "they are regularly spirally twisted when at rest." The brachia, however, in all recent species, are recurved and more or less spirally enrolled, except in some gerontic forms of loop-bearing genera, as Cistella and Gwynia. Therefore Helictopoda, as far as the brachial structure is concerned, will also include the Ancylopoda. In fact, to the former Gray referred only the terebratuloids, if Thecidia is

[1] Palæontology of New York, Vol. VIII, Part II, 1895, p. 334.

Digitized by Google

excluded, while the Ancylopoda contained all other brachiopods, both articulate and inarticulate forms. These subclasses are further divided, on the basis of the brachia, into four orders: Ancylobrachia, Cryptobrachia, Sclerobrachia, and Sarcicobrachia. Of these the first only has value as a superfamily, since it includes the "loop bearing" genera, or Terebratulacea. The other orders have so heterogeneous an assemblage of forms as to be of no permanent value.

Beyond the introduction of new families, no further attempt was made by writers to divide the Brachiopoda into other orders than Lyopomata and Arthropomata until 1883, when Waagen published his great work on the fossils of this class from the Salt Range group of India. He found it "absolutely necessary" to further divide the Lyopomata and Arthropomata into seven suborders. The basis for these suborders has no underlying principle of general application, yet the majority of the divisions are of permanent value, for each contains an assemblage of characters not to be found in any of the others. Waagen's genealogy of the Arthropomata, with Orthis as the prototype, falls at once to the ground, since the comprehensive studies of the genus Orthis by Hall and Clarke have shown that it is questionable "whether any of these primordial forms can be included under Orthis according to the strict definition of the term or even under any of the subdivisions"[1] proposed by them. There are, however, a few species in the Upper Cambrian which seem to agree with such dalmanellas as *O. subæquata*, but these originated long after many undoubted Protremata and Telotremata had lived in the Lower and Middle Cambrian. Lingula, on the other hand, was usually regarded as the prototype of all brachiopods, but this is also impossible, since a number of inarticulate genera flourished for ages before Lingula was developed.

PRINCIPLES OF CLASSIFICATION.

No classification can be natural and permanent unless based on the history of the class (chronogenesis) and the ontogeny of the individual. However, as long as the structure of the early Paleozoic genera of Brachiopoda remained practically unknown and the ontogeny untouched, nothing of a permanent nature could be attempted. In the recent volumes by Hall and Clarke many of these early genera are clearly defined, so that their structures and geologic sequence are now far more accurately known. The ontogenetic study of Paleozoic species was initiated in 1891 by Beecher and Clarke, and was continued by Beecher and Schuchert. These results, combined with those derived from the development of some recent species, and published by Kovalevsky, Morse, Shipley, Brooks, Beecher, and others, confirm the conclusions reached through chronogenesis. Moreover, the application by Beecher of the law of morphogenesis, as defined by Hyatt, and the

[1] Palæontology of New York, Vol. VIII, Part I, 1892, p. 218.

Digitized by Google

recognition and establishment of certain primary characters have resulted in the discovery of a fundamental structure of general application for the classification of these organisms. It has for its basis the nature of the pedicle opening and the stages of shell growth. On these characters Beecher has divided the class into four orders—the Atremata, Neotremata, Protremata, and Telotremata.[1]

Hall and Clarke[2] reject Beecher's ordinal terms Atremata and Neotremata for the subordinal names Mesokaulia and Daikaulia of Waagen, on the ground of priority, and because the latter terms are "an admirable expression of the significance of the pedicle passage." If some of Waagen's subordinal terms are elevated to ordinal rank and amended by Hall and Clarke, then these terms are no longer Waagen's, but should be credited to Hall and Clarke. Such being the case, the law of priority demands the retention of Beecher's terms, as they do not conflict with those of Waagen but with the secondary definition and rank accorded them by Hall and Clarke.

On the other hand, Dall claims[3] that "names of higher rank than genera are not subject to the rule of strict priority, on account of the mutability of their limits." Again, if Waagen's subordinal terms (and there are seven of them) are to be elevated to ordinal rank—i. e., if the characters upon which they are established are ordinal characters—then all should be elevated alike in rank. Besides the two mentioned above, Hall and Clarke accept also Gasteropegmata and Helicopegmata. The latter, however, they retain as suborders, and would do likewise with Kampylopegmata if Gray's term Ancylobrachia of earlier date did not cover the same group of brachiopods; while Gasteropegmata, having certainly no greater value than a superfamily, is elevated to an order. Again, they accept Beecher's Protremata, when Waagen's suborder Aphaneropegmata could as well be raised to ordinal rank and adapted so as to include the former, since Waagen based the latter upon families having the diagnostic character of the Protremata, namely, the well-developed deltidium. However, a far more important reason why Waagen's terms should not be elevated to ordinal rank and made to displace Beecher's names is that the latter clearly understood the value of the different ordinal characters and defined them excellently, which definitions are accepted by Hall and Clarke. He pointed out the most primitive shelled condition in the protegulum, and found this first shell-growth stage in all the important families in the class. He observed that not the mere pedicle slit of the Daikaulia is the ordinal character for Neotremata, but the way in which growth proceeds to form this derived pedicle slit from the open pedicle notch of primitive forms. He was the first to interpret the true morphologic

[1] Development of the Brachipoda, Part I, Am. Jour. Sci., 3d series, Vol. XLI, 1891; Part II, ibid., Vol. XLIV, 1892.

[2] Palæontology of New York, Vol. VIII, Part II, summary, 1895.

[3] Trans. Wagner Free Institute of Science, Phila., Vol. III, Part III, 1895, p. 565, Rule XII.

Digitized by Google

meaning of the deltidium and deltidial plates, and subsequently, from the works of others, chiefly Kovalevsky, was able to demonstrate the great morphologic significance of the deltidium. Without any injustice to the monumental work of Waagen—and there is no more careful work on the Brachiopoda—it can safely be asked, Were Waagen's suborders based on a fundamental morphologic character of general importance throughout or on ontogeny? Mesokaulia and Daikaulia are the only two of the seven suborders having, as now understood, the required ordinal characters, and these divisions were established by Waagen on the form, general expression, and the position of the pedicle, and not on the morphologic development of the pedicle opening. Four of the other five suborders are based on superfamily and the fifth on family characters. Five of Waagen's seven suborders, therefore, are here retained as superfamilies, and practically in the sense of their author.

Since orders are established on the nature of the pedicle opening, persistent internal characters of the shell are, as a rule, used for superfamily purposes. Such are the absence or presence of a spondylium (Strophomenacea and Pentameracea, respectively); the absence or presence of calcareous brachial supports, and their nature (crura only in the Rhynchonellacea, loop in the Terebratulacea, and spirals in the Spiriferacea).

Families within the superfamilies are based upon a combination of external and internal generic characters common to many genera, or even to one genus. Such characters are: Outer form; nature and position of muscles (Obolidæ, Lingulidæ, etc.); internal plates (Trimerellidæ, Lingulasmatidæ, Pentameridæ); peculiarities of the cardinal process (Orthidæ, Strophomenidæ); imperfection or perfection or persistent peculiarities of ordinal and superfamily characters (Orthidæ, Trematidæ, Discinidæ, Siphonotretidæ, etc.); simplicity or complexity of the jugum (Hindellinæ, Diplospirinæ, etc.); and occasionally the nature of the shell structure (Rhynchospirinæ). When families are large it is not rare to find groups of genera having a common origin which have characters in common but not differentiated sufficiently to introduce new characters of family importance. In such cases it is advisable to divide the family into subfamilies, which facilitates systematic review and discussion. Such is the case in the large families Strophomenidæ, Terebratulidæ, Terebratellidæ, Spiriferidæ, and Athyridæ.

No division, however, has any value unless the group contains forms of but one phylum. A phylum, or line of descent, can not originate twice. It happens, however, that the same or nearly the same combination of mature characters is developed along different phyla. When this occurs the ontogeny will show it. It is therefore not correct to group these different stocks as belonging to one family. For instance,

Digitized by Google

the Trimerellidæ and Lingulasmatidæ have family structures in common and were referred to the same family. Ontogeny and chronogenesis, however, show that the former family originated directly in the Obolidæ, while the latter was not evolved from the linguloid phylum until the Obolidæ had given origin to the Lingulellidæ and the Lingulidæ. Again, the family Terebratellidæ, probably during early Mesozoic times, divided, one stock drifting into boreal and another into austral regions. These two stocks agree in the earliest shelled condition and at maturity, but between these two stages of growth the austral group (Magellaninæ) passes through a series of loop metamorphoses different from that through which the boreal group (Dallinæ) passes. Therefore it is unnatural to include both in one subfamily, as was formerly done.

It was by the application of the above-mentioned principles that the writer, in 1893, arranged all brachiopod genera under the four orders instituted by Beecher. Since then this subject has received considerable attention, and the many Cambrian brachiopods brought together by Walcott have been examined as to their generic structures. These studies have led to some changes in the classification which follows, the most important being that the order Telotremata could not have originated in the Pentameriidæ, since no Pentameracea are known in the Cambrian until long after that order had representation. The divisions Lyopomata and Arthropomata, introduced by Deshayes and Owen, have been abandoned for reasons given in previous pages.

CLASSIFICATION AND SYNONYMY.[1]

Class BRACHIOPODA Cuvier, 1802; Duméril, 1

Spirobranchiophora Gray, 1821; Palliobranchiata Blainville, 1824; Branchiopoda Risso, 1826 (not Latreille); Brachiopodidæ Broderip, 1839; Branchionopoda Agassiz, 1847; Brachionocephala Bronn, 1862; Spirobranchia Bronn, 1862; Branchionobranchia Paetel, 1875.

Bivalved Molluscoidea with inequivalved, equilateral shells attached to extraneous objects by a posterior prolongation of the body, or pedicle, (1) throughout, (2) during a portion of life, or (3) cemented ventrally. Valves ventral and dorsal. In composition, phosphatic or calcareous, or both. Animal consisting of two pallial membranes intimately related to the shell. Within the mantle cavity at the sides of the mouth are inserted the two, more or less long, oral, usually spirally enrolled, cirrated brachia, which are variously modified, and are supported in the two terminal superfamilies by an internal calcareous skeleton, or brachidium, attached to the dorsal valve. Anus present or absent. Central nervous system consisting of an œsophageal ring, with weakly

[1] All names in small type and indented are synonyms of the term in larger type immediately preceding.

Digitized by Google

developed brain and infraœsophageal ganglionic swellings. Blood-vascular system probably present, with the sinuses developed into vascular dilatations at the back of the stomach and elsewhere. Sexes separate. Exclusively inhabitants of the sea. The class is present in the Lower Cambrian, attained maximum development in the Silurian and Devonian, and is represented by about 140 living species. During this time, probably upward of 6,000 fossil and recent species have been developed, and these are distributed in 328 genera, grouped in 31 families, 10 superfamilies, and 4 orders.

Order ATREMATA Beecher, 1891.[1]

Mesokaulia, or Lingulacea (partim) Waagen, 1885.

Inarticulate Brachiopoda with the pedicle emerging freely between the two valves, the opening being more or less shared by both. Growth taking place mainly around the anterior and lateral margins, never inclosing or surrounding the pedicle. Aperture unmodified. Prodeltidium attached to dorsal valve.

Superfamily OBOLACEA Schuchert, 1896.[2]

Rounded or semicircular and more or less lens-shaped, thick-shelled, primitive Atremata, fixed by a short pedicle throughout life to extraneous objects.

1.[3] Family PATERINIDÆ Schuchert, 1893 (emend.).[4]

Obolacea with the dorsal valve semicircular and the ventral subcircular in outline. Posterior region more or less closed by cardinal areas.

Iphidea Billings, 1872.
Paterina Beecher, 1891.

Volborthia von Möller, 1873.

2. Family OBOLIDÆ King, 1846.

Obolinæ Gill, 1871.

Thick-shelled Obolacea of nearly circular or ovoid outline, biconvex, usually smooth, with rudimentary cardinal areas traversed by shallow

[1] Since in this classification no superordinal terms are for the present adopted, it will be well to give here all such terms used by authors and others which are of lower rank and not readily referred as synonyms to their proper places:

Ancylobrachia Ancylopoda, Helictopoda, Sarcicobrachia Gray, 1848; Lyopomata and Arthropomata Owen, 1858; Pleuropygia, Sarcicobranchiona, Sclerobranchiona Bronn, 1862; Articulata and Inarticulata Huxley, 1864; Clistenterata and Tretenterata King, 1873.

[2] Text book of Paleontology, by Zittel and Eastman, 1896, p. 305. Also see page 78 of this bulletin.

[3] The numbers and letters before a family or subfamily term indicate the phyletic relations which these have to one another within a superfamily. The phylogeny of the families, however, is more clearly represented in the diagram on Pl. I, facing p. 134.

[4] Recent discoveries have shown that Iphidea has no pedicle opening, and should include forms referred to Paterina. Therefore this family is of doubtful value, and is provisionally retained for the reception of genera more primitive in structure than those of the Obolidæ.

Digitized by Google

pedicle grooves. Muscular scars distinct, consisting of two pairs of adductors and three of sliders, or adjustors.

Obolella Billings, 1861.
  Dicellomus Hall, 1871.
Elkania Ford, 1886.
  Billingsia Ford, 1886.
Neobolus Waagen, 1885.
Botsfordia Matthew, 1893.
?Spondylobolus McCoy, 1852.
Obolus Eichwald, 1829.
  Ungula Pander, 1830.
  Ungulites Bronn, 1848.
  Aulontreta Kutorga, 1848.
  Euobolus Mickwitz, 1896.
Acritis Volborth, 1869.
Schmidtia Volborth, 1869 (not Bals-Criv., 1863).
Thysanotos Mickwitz, 1896.
Leptembolon Mickwitz, 1896.

3. Family TRIMERELLIDÆ Davidson and King, 1874.

Large, thick-shelled, inequivalved Obolacea, with the ventral cardinal area usually very prominent, triangular, and transversely striated. Adjustors and anterior adductor muscles elevated upon solid or deeply excavated platforms, or spondylia.

?Lakmina Œhlert, 1887.
  Davidsonella Waagen, 1885 (not Munier-Chalmas, 1880).
Lingulobolus Matthew, 1896.
Sphærobolus Matthew, 1896.
Dinobolus Hall, 1871.
  Conradia Hall, MS., 1862.
  Obolellina Billings, 1871.
  Ungulites Quenstedt, 1871 (not Bronn, 1848).
Monomorella Billings, 1871.
Trimerella Billings, 1862.
  Gotlandia Dall, 1870.
Rhinobolus Hall, 1874.

Superfamily **LINGULACEA** Waagen, 1885 (restricted).[1]

Elongate, thin-shelled, burrowing, derived Atremata, with a more or less long, worm-like, tubular, flexible pedicle.

1. Family LINGULELLIDÆ Schuchert, 1893.

Spatulate, inequivalved Lingulacea, structurally intermediate between the Obolidæ and Lingulidæ.

Lingulella Salter, 1866.
Lingulepis Hall, 1863.
Leptobolus Hall, 1871.
?Paterula Barrande, 1879.
  Cyclus Barrande, 1879.
?Mickwitzia Schmidt, 1888.

[1] Waagen's term Mesokaulia, or Lingulacea, is based upon the families Obolidæ, Trimerellidæ, and Lingulidæ. Since this term has value, and to avoid proposing another, Lingulacea is here restricted to the latter family and two others recently proposed. Waagen in using this term gave a dual series; the second one is here adopted to conform in euphony with other superfamily terms.

Digitized by Google

2. Family LINGULIDÆ Gray, 1840.

Lingulidæ Gill, 1871.

Attenuate, subquadrate or spatulate, almost equivalved Lingulacea, derived through Lingulellidæ, with a more or less long, tubular, flexible pedicle. Muscles highly differentiated and consisting of six pairs, two of adductors, and four of sliders, or adjustors.

Lingula Bruguière, 1792.
Pharetra Bolton, 1798.
Lingularius Duméril, 1806.
Glossina Phillips, 1848.
Dignomia Hall, 1871.
Glottidia Dall, 1870.
Barroisella Hall and Clarke, 1892.
Tomasina Hall and Clarke, 1892.

3. Family LINGULASMATIDÆ Winchell and Schuchert, 1893.

Platform-bearing Lingulacea derived through Lingulidæ.

Lingulops Hall, 1871.
Lingulasma Ulrich, 1889.
Lingulelasma Miller, 1889.

Order TELOTREMATA Beecher, 1891.

Sclerobrachia Gray, 1848; Kampylopegmata (partim) Waagen, 1883; Pegmatobranchiata (partim) Neumayr, 1883.

Articulate Brachiopoda, with the pedicle opening shared by both valves in nepionic and early neanic stages, usually confined to one valve in later stages, and becoming more or less modified by deltidial plates in ephebic stages. Brachia supported by calcareous crura, loops, or spiralia. Prodeltidium absent.

Superfamily RHYNCHONELLACEA Schuchert, 1896.[1]

Rostracea Schuchert, 1893; Ancistropegmata (partim) Zittel, 1895.

Rostrate, primitive Telotremata, with or without crura.

1. Family PROTORHYNCHIDÆ Schuchert, 1896.[1]

Primitive Rhynchonellacea, without deltidial plates or crura.

Protorhyncha Hall and Clarke, 1893.

2. Family RHYNCHONELLIDÆ Gray, 1848.

Hypothyridæ (partim) King, 1850; Rhynchonellinæ Gill, 1871; Waagen, 1883.

Rhynchonellacea with more or less long crura.

[1] Text-book of Paleontology, by Zittel and Eastman, 1896, p. 323.

Digitized by Google

Orthorhynchula Hall and Clarke, 1893.
Rhynchotrema Hall, 1860.
Stenochisma Conrad, 1839; Hall, 1867.
Rhynchotreta Hall, 1879.
Camarotœchia Hall and Clarke, 1893.
Plethorhynchus Hall and Clarke, 1893.
Leiorhynchus Hall, 1860.
Wilsonia Kayser, 1871.
Uncinulina Bayle, 1878.
Uncinulus Bayle, 1878.
Hypothyris King, 1846 (not Phillips, 1841).
Pugnax Hall and Clarke, 1893.
Eatonia Hall, 1857.
Cyclorhina Hall and Clarke, 1893.
Rhychopora King, 1856.
Rhynchoporina Œhlert, 1887.
Terebratuloidea Waagen, 1883.
Rhynchonella Fisher de Waldheim, 1809.
Oxyrhynchus Llhwyd, 1699 (not Aristotle).
Rhyngonella Bronn, 1849.
Bicornes Quenstedt, 1851.
Rhynchonellopsis Bose, 1894.
Halorella Bittner, 1890.
Austriella Bittner, 1890.
Norella Bittner, 1890.
Peregrinella Œhlert, 1887.
Rhynchonellina Gemmelaro, 1871.
Dimerella Zittel, 1870.
Acanthothyris d'Orbigny, 1850.
Hemithyris d'Orbigny, 1847.
Frieleia Dall, 1895.
Cryptopora Jeffreys, 1869.
Atretia Jeffreys, 1876.
Neatretia Œhlert, 1891.

Superfamily **TEREBRATULACEA** Waagen, 1883 (restricted).[1]

Ancylopoda, Cryptobrachia, and Ancylobrachia (partim) Gray, 1848; Kampylopegmata Waagen, 1883; Ancylopegmata Zittel, 1895.

Derived Telotremata with the brachia supported by calcareous, primitive, or metamorphosed loops.

Section A. *TEREBRATULA.*

Terebratulacea with the loops unsupported by a median dorsal septum at any stage of growth. Brachial cirri directed outward in larval stages.

1. Family CENTRONELLIDÆ Hall and Clarke, 1895.[2]

Centronellinæ Waagen, 1882; Beecher, 1893; Rensselæridæ Hall and Clarke, 1895.

Terebratulas with the loop developing direct and composed of two descending lamellæ, uniting in the median line and forming a broad, arched plate.

[1] Terebratulacea Waagen is used here in preference to Ancylobrachia Gray, in violation of the law of priority, for the sake of euphony.

[2] Since Beecher's "Revision of the families of loop-bearing Brachiopoda" (Trans. Conn. Acad., Vol. IX, 1893), it has been shown by Beecher and Schuchert (Proc. Biol. Soc. Washington, Vol. VIII, 1893) that the loop in the family Terebratulidæ, as limited in the former paper, does in part pass through a short series of metamorphoses. This necessitates the removal of Centronellinæ from the family Terebratulidæ, since its loops remain essentially without change throughout growth.

Digitized by Google

Rensselæria Hall, 1859.
Beachia Hall and Clarke, 1893.
Newberria Hall, 1891.
Rensselandia Hall, 1867.
Oriskania Hall and Clarke, 1893.
Trigeria (Bayle, 1875?) Hall and Clarke, 1893.
?Scaphiocœlia Whitfield, 1891.
Centronella Billings, 1859.
Cryptonella Hall, 1863 (not 1861 and 1867).
Chascothyris Holzapfel, 1895.
Selenella Hall and Clarke, 1893.
Romingerina Hall and Clarke, 1893.
Juvavella Bittner, 1888.
Juvavellina Bittner, 1896.
Nucleatula (Zugmayer) Bittner, 1890.
Dinarella Bittner, 1892.
?Lissopleura Whitfield, 1896.

2. Family TEREBRATULIDÆ Gray, 1840.

Terebratulas developing originally a Centronella-like loop, and thence by a short series of metamorphoses resulting at maturity in a free loop of varying form.

Subfamily STRINGOCEPHALINÆ Dall, 1870.

Stringocephalidæ King, 1850; Davidson, 1853.

Terebratulidæ with a "long loop, following the margin of the dorsal valve, not recurved in front. Probably no median coiled arm" (Beecher).[1]

Stringocephalus Defrance, 1827.

2a. Subfamily MEGALANTERINÆ Waagen, 1882.

Terebratulidæ with a long loop having ascending branches.

Megalanteris Œhlert, 1887.
Meganteris Suess, 1855.
?Cryptacanthia White and St. John, 1868.
Cryptonella Hall (1861?), 1867.
Harttina Hall and Clarke, 1893.

2a[1]. Subfamily TEREBRATULINÆ Dall, 1870.

Terebratulidæ with a short loop. "A median unpaired coiled arm exists in recent genera" (Beecher).

Eunella Hall and Clarke, 1893.
Cranæna Hall and Clarke, 1893.
Dielasma King, 1859.
Epithyris King, 1850 (not Phillips, 1841).
Seminula McCoy, 1855 (not 1844).
Dielasmina Waagen, 1882.
Notothyris Waagen, 1882.
Zugmeyeria Waagen, 1882.
Dictyothyris Douvillé, 1880.
Glossothyris Douvillé, 1880.
Pygope Link, 1830.

[1] The ontogenetic history of Stringocephalus is not known. Its mature loop, however, is so different from that of the Centronellidæ that it appears probable that this appendage passed through a short series of changes, and therefore the reference of this subfamily to the Terebratulidæ.

Digitized by Google

Beecheria Hall and Clarke, 1893.
Hemiptychina Waagen, 1882.
Rhætina Waagen, 1882.
Terebratula Klein, 1753.
Terebratula Llhwyd, 1699.
Sacculus Llhwyd, 1699.
Lampas Meuschen, 1787.
Terebratularius Duméril, 1806.
Nucleata Quenstedt, 1871.
Musculus Quenstedt, 1871 (not Klein, 1753).
Diphyites Schroter, 1799.
Pugites de Hann, 1833.
Antinomia Catullo, 1850.
Propygope Bittner, 1890.
Liothyrina Œhlert, 1887.
Epithyris Deslongchamps, 1862 (not King, 1848).
Gryphus Megerle, 1811 (not Brisson, 1760).
Liothyris Douvillé, 1880 (not Conrad, 1875).
Terebratulina d'Orbigny, 1847.
? Disculina Deslongchamps, 1884.

2a[b]. Subfamily DISCOLIINÆ Beecher, 1893.

Discoliidæ Fischer and Œhlert, 1892.

Terebratulidæ with the "loop short and continuous with the cirrated edge of the lophophore. No coiled median arm" (Beecher).

Discolia Fischer and Œhlert, 1890.
Eucalathis Fischer and Œhlert, 1890.
? Agulhasia King, 1871.

Section B. *TEREBRATELLA.*

Terebratulacea with the loop supported by a median dorsal septum throughout life, or only in the younger stages. Brachial cirri directed inward during larval stages. This section has two phyla having a common origin now geographically separated in two provinces, one austral, the other boreal.

1. Family TEREBRATELLIDÆ King, 1850 (emend Beecher, 1893).

Waldheimidæ Douvillé, 1880; Waldheimiinæ Waagen, 1882.

Terebratulacea with the "loop in the higher genera composed of two primary and two secondary lamellæ, passing through a series of distinct metamorphoses while attached to a dorsal septum" (Beecher).

1. Subfamily TROPIDOLEPTIINÆ Schuchert, 1896.[1]

Terebratellidæ with the loop consisting of two slender descending branches, uniting with a high, vertical septum. Apparently the ancestral stock for the Terebratellidæ.

Tropidoleptus Hall, 1859.

[1] Text-book of Paleontology, by Zittel and Eastman, 1896, p. 330.

Digitized by Google

1a. Subfamily MEGATHYRINÆ Dall, 1870 (emend Beecher, 1893).

Argiopidæ King, 1850; Megathyridæ Œhlert, 1887; Argiopidæ Davidson, 1884; Argiopinæ Davidson, 1887.

Terebratellidæ in which the "loop is composed of descending branches only, passing in the highest genus through stages correlative with Gwynia, Cistella, and Megathyris. The lower genera do not complete the series" (Beecher). The original stock for the two following subfamilies:

Megathyris d'Orbigny, 1847.
  Argiope Deslongchamps, 1842 (not Savigny and Audouin, 1827).
Zellania Moore, 1854.
Gwynia King, 1859.
Cistella Gray, 1850.

1a[a]. Subfamily DALLINÆ Beecher, 1893.[1]

Platidiinæ Dall, 1870.

Terebratellidæ with the "loop composed of descending and ascending lamellæ, passing in the highest genera through metamorphoses comparable to the adult structure of Platidia, Ismenia, Mühlfeldtia, Terebratalia, and Dallina. The lower genera, therefore, do not progress to the final stages" (Beecher). Recent genera restricted to boreal seas.

Dallina Beecher, 1893.
Macandrevia King, 1859.
Terebratalia Beecher, 1893.
Lacqueus Dall, 1870.
  Frenula Dall, 1871.
Frenulina Dall, 1895.
Mühlfeldtia Bayle, 1880.
  Megerlia King, 1850 (not Robineau Desvoidy, 1830).
Platidia Costa, 1852.
  Morrisia Davidson, 1852.
Ismenia King, 1850 (not Dall, 1871).
Kingena Davidson, 1852.
  Kingia Schoenbach, 1867.
Trigonosemus Koenig, 1825.
  Fissurirostra d'Orbigny, 1847.
  Fissirostra d'Orbigny, 1847.
  Delthyridea King, 1850.
Lyra Cumberland, 1816.
  Terebrirostra d'Orbigny, 1847.
Eudesia King, 1850.
  Orthotoma Quenstedt, 1871.
  Trigonella Quenstedt, 1871.
  Flabellothyris Deslongchamps, 1884.
Zeilleria Bayle, 1878.
Fimbriothyris Deslongchamps, 1884.
Microthyris Deslongchamps, 1884.
  Ornithella Deslongchamps, 1884.
Aulacothyris Douvillé, 1880.
Camerothyris Bittner, 1890.
Epicyrta Deslongchamps, 1884.
Cincta Quenstedt, 1871.
Antiptychina Zittel, 1883.
Plesiothyris Douvillé, 1880.
?Hynniphoria Suess, 1858.
?Cruratula Bittner, 1890.
?Orthoidea Friren, 1875.

[1] Since many of the fossil genera here referred to this family have not been studied in the light of Beecher's and Œhlert's recent researches, it is not known that all belong to this boreal stock.

Digitized by Google

1a[b]. Subfamily MAGELLANINÆ Beecher, 1893.

Waldheimidæ (partim) Douvillé, 1880; Terebratellinæ and Magasinæ Davidson, 1887; Magasidæ (partim) d'Orbigny, 1847; King, 1850; Rhynchoridæ (partim) King, 1850; Mühlfeldtiinæ Œhlert, 1887; Kraussininæ Dall, 1870; Kraussidæ Davidson, 1870.

Terebratellidæ with the "loop composed of descending and ascending branches, passing in the higher genera through metamorphoses comparable to the adult structure of Bouchardia, Magas, Magasella, Terebratella, and Magellania. The lower genera become adult before reaching the terminal stages" (Beecher). Recent genera are restri ted to austral seas.

Magellania Bayle, 1880.
- Waldheimia King, 1850 (not Brulle, 1846).
- Neothyris Douvillé, 1880.

Terebratella d'Orbigny 1847.
- Delthyris Menke, 1830 (not Dalman, 1828).
- Ismenia King, 1850 (not Dall, 1870).
- Waltonia Davidson, 1850.

Magasella Dall, 1870.
Rhynchorina Œhlert, 1887.
Magas Sowerby, 1816.
Megerlina Deslongchamps, 1884.
Bouchardia Davidson, 1849.
- Pachyrhynchus King, 1850.

Kraussina Davidson, 1859.
- Kraussia Davidson, 1852 (not Dana, 1852).

Cœnothyris Douvillé, 1880.
Mannia Dewalque, 1874.
? Rhynchora Dalman, 1828.

Superfamily SPIRIFERACEA Waagen, 1883.

Helicopegmata Waagen, 1883.

Telotremata with the adult brachia supported by calcareous spiral lamellæ or spiralia.

1. Family ATRYPIDÆ Gill, 1871.

Atrypidæ Dall, 1877.

Spiriferacea with the crura directly continuous with the primary lamellæ, which diverge widely and have the spiral cones between them. Jugum simple, complete or incomplete.

1a. Subfamily ZYGOSPIRINÆ Waagen, 1883.

Anazygidæ Davidson, 1884; Zygospiridæ Hall and Clarke, 1895.

Atrypidæ with a simple jugum either posteriorly or anteriorly directed. Spiralia with their apices toward the median dorsal region.

Zygospira Hall, 1862.
- Stenocisma Hall, 1864 (not Conrad, 1839; Hall, 1867).
- Anazyga Davidson, 1882.
- Orthonomæa Hall, 1858.
- Hallina Winchell and Schuchert, 1892.
- Protozyga Hall and Clarke, 1893.

Catazyga Hall and Clarke, 1893.
Atrypina Hall and Clarke, 1893.
Glassia Davidson, 1882.
? Clintonella Hall and Clarke, 1893.

Digitized by Google

Subfamily DAYINÆ Waagen, 1883.

Atrypidæ with the jugum drawn out posteriorly into a simple short process. Spiralia laterally directed.

Dayia Davidson, 1882.

1a*. Subfamily ATRYPINÆ Waagen, 1883.

Atrypidæ with the jugum situated extremely posterior, complete in young stages, but at maturity discontinuous. Spiralia dorso-medially directed.

Atrypa Dalman, 1828.
- Cleiothyris Phillips, 1841 (not King, 1830).
- Spirigerina d'Orbigny, 1874.

Gruenewaldtia Tschernyschew, 1885.

?Karpinskya Tschernyschew, 1885.

2. Family SPIRIFERIDÆ King, 1846 (emend Davidson).

Martiniinæ and Reticulariinæ Waagen, 1883; Spiriferinidæ Davidson, 1884.

Spiriferacea with the crura directly continuous with the bases of the primary lamellæ, which are situated between the laterally directed spiralia. Jugum simple, complete or incomplete.

2a. Subfamily SUESSIINÆ Waagen, 1883.

Spiriferidæ with the jugum continuous and more or less V-shaped. Shell structure punctate.

Cyrtina Davidson, 1858.

Theocyrtella Bittner, 1892.
- Cyrtotheca Bittner, 1890 (not Salter).

Spiriferina d'Orbigny, 1847.

Suessia Deslongchamps, 1854.

Subfamily UNCITINÆ Waagen, 1883.

Spiriferidæ (?) with the jugum as in Suessiinæ. Just within the posterior margin of the dorsal valve are pouch-like plates. Deltidial plates united, deeply concave. Subfamily anomalous.

Uncites Defrance, 1825.

?Uncinella Waagen, 1883.

2b. Subfamily TRIGONOTRETINÆ Schuchert, 1893.

Delthyrinæ (partim) Waagen, 1883.

Spiriferidæ with the jugum at maturity discontinuous, represented by two short jugal processes, one attached to each primary lamella.

?Cyclospira Hall and Clarke, 1893.

Spirifer Sowerby, 1815.
- Choristites Fisher de Waldheim, 1825.
- Trigonotreta Koenig, 1825; Meek and Hayden, 1864.
- Spiriferus Blainville, 1827.
- Spirifera J. de C. Sowerby, 1835.
- Brachythyris McCoy, 1844.
- Fusella McCoy, 1844.
- Hysterolithus Quenstedt, 1871.

Cyrtia Dalman, 1828.

Syringothyris Winchell, 1863.
- Spirifer Meek and Hayden, 1864.

Delthyris Dalman, 1828.

Martinia McCoy, 1844.

Martiniopsis Waagen, 1883.

Mentzelia Quenstedt, 1871.

Ambocœlia Hall, 1860.

Reticularia McCoy, 1844.

Verneuilia Hall and Clarke, 1893.

?Metaplasia Hall and Clarke, 1893.

Digitized by Google

3. Family ATHYRIDÆ Phillips, 1841.

Nucleospiridæ Davidson, 1882; Koninckinidæ Davidson, 1853.

Spiriferacea with the bases of the primary lamellæ situated between the spiralia, and sharply recurved dorsally at their junction with the crura. Spiralia more or less laterally directed. Jugum complete, V-shaped, with the apex drawn out into a simple, bifurcated, or otherwise modified process.

3a. Subfamily RHYNCHOSPIRINÆ Schuchert, 1894.

Retziinæ Waagen, 1883; Retziidæ and Rhynchospiridæ Hall and Clarke, 1895.

Athyridæ with the single process of the jugum commonly recurved, but sometimes bifurcated. Shell structure distinctly punctate.

Homœospira Hall and Clarke, 1893.
Rhynchospira Hall, 1859.
Ptychospira Hall and Clarke, 1893.
Eumetria Hall, 1864.
Trematospira Hall, 1857.
Parazyga Hall and Clarke, 1893.
Acambona White, 1862.
Hustedia Hall and Clarke, 1893.
Retzia King, 1850.
  Trigeria Bayle, 1878.

3a. Subfamily HINDELLINÆ Schuchert, 1894.

Cœlospiridæ and Nucleospiridæ Hall and Clarke, 1895.

Athyridæ in which the jugum has a single process which may be simple, or it articulates in a ventral septal socket, and sometimes (rarely) is sharply recurved terminally. Shell structure impunctate.

Hindella Davidson, 1882.
Whitfieldella Hall and Clarke, 1893.
  Meristina Davidson, 1882 (not Hall, 1867).
Nucleospira Hall, 1858.
Hyattella Hall and Clarke, 1893.
Anoplotheca Sandberger, 1856.
  Bifida Davidson, 1882.
Cœlospira Hall, 1863.
  Leptocœlia Hall, 1857, 1859.
Vitulina Hall, 1860.
?Anabia Clarke, 1893.

3b. Subfamily ATHYRINÆ Waagen, 1883.

Athyridæ in which the single process of the jugum bifurcates. The branches may or may not terminate between the first and second volutions of the spiralia.

Meristina Hall, 1867.
  Athyris Davidson, 1853 (not McCoy, 1844).
  Whitfieldia Davidson, 1882.
Glassina Hall and Clarke, 1893.
Athyris McCoy, 1844.
  Spirigera d'Orbigny, 1847.
  Euthyris Quenstedt, 1871.
Actinoconchus McCoy, 1844.
Torynifer Hall and Clarke, 1895.
Cleiothyris King, 1840 (not Phillips, 1841).
Seminula McCoy, 1844.
Spirigerella Waagen, 1883.
Anomactinella Bittner, 1890.
Pomatospirella Bittner, 1892.
Amphitomella Bittner, 1890.
Tetractinella Bittner, 1890.
  Plicigera Bittner, 1890.
Pentactinella Bittner, 1890.

Digitized by Google

3c. Subfamily DIPLOSPIRINÆ Schuchert, 1894.

Athyridæ (partim) Hall and Clarke, 1895.

Athyridæ with the jugal bifurcations very long, lying between the volutions of the spiralia, and continuing with these to their outer ends. Sometimes there is an additional jugal process which articulates with the ventral valve, or recurves and joins the jugum.

Kayseria Davidson, 1882.
Diplospirella Bittner, 1890.
Euractinella Bittner, 1890.
Pexidella Bittner, 1890.
Anisactinella Bittner, 1890.
?Didymospira Salomon.

3bb. Subfamily KONINKININÆ Waagen, 1883.

Koninckinidæ Davidson, 1853; Amphiclininæ Waagen, 1883; Diplospidæ and Diplospiridæ Munier-Chalmas, 1880.

Athyridæ with jugum and spiralia essentially as in Diplospiridæ. The spiralia in Koninckininæ, however, are not laterally directed as in the former group, but point ventrally, this being due to the concave form of the dorsal shell.

Koninckina Suess, 1853.
Amphiclina Laube, 1865.
Koninckella M.-Chalmas, 1880.
Koninckodonta Bittner, 1893.
?Thecospira Zugmeyer, 1880.
?Amphiclinodonta Bittner, 1890.

3ba. Subfamily MERISTELLINÆ Waagen, 1883.

Meristellidæ Hall and Clarke, 1895.

Athyridæ in which the jugal bifurcations do not enter the spiralia, but recurve and join near their origin.

Meristella Hall, 1860.
Charionella Billings, 1861.
?Pentagonia Cozzens, 1846.
Goniocœlia Hall, 1861.
Dicamara Hall and Clarke, 1893.
Merista Suess, 1851.
Camarium Hall, 1859.
Dioristella Bittner, 1890.
?Camarospira Hall and Clarke, 1893.

Order NEOTREMATA Beecher, 1891.

Circular or oval, more or less cone-shaped, inarticulate Brachiopoda, with the pedicle opening restricted throughout life to the ventral valve. Pedicle aperture modified by a deltidium or listrium. Prodeltidium attached to the ventral valve.

Superfamily ACROTRETACEA Schuchert, 1896.[1]

Daikaulia (partim) Waagen, 1885; Diacaulia Hall and Clarke, 1895.

Neotremata with phosphatic shells and a more or less well-developed pseudodeltidium. Dorsal protegulum marginal.

[1] Text-book of Paleontology, by Zittel and Eastman, 1896, p. 308.

Digitized by Google

1. Family ACROTRETIDÆ Schuchert, 1893.

Acrotretacea with the pedicle opening posterior to the protegulum.

Acrothele Linnarsson, 1876.
Linnarssonia Walcott, 1885.
Discinopsis (Matthew) Hall and Clarke, 1892.
Acrotreta Kutorga, 1848.
Conotreta Walcott, 1889.
?Mesotreta Kutorga, 1848.
?Orbicella d'Orbigny, 1849.
Keyserlingia Pander, 1861.
?Helmersenia Pander, 1861.

2. Family SIPHONOTRETIDÆ Kutorga, 1848.

Acrotretacea with the pedicle opening passing by resorption anteriorly through the protegulum and the umbo of the shell.

Yorkia Walcott, 1897.
Trematobolus Matthew, 1893.
Siphonotreta de Verneuil, 1845.
Protosiphon Matthew, 1897
Schizambon Walcott, 1884.
Schizambonia Œhlert, 1887.

Superfamily **DISCINACEA** Waagen, 1885.

Daikaulia (partim) Waagen, 1885; Diacaulia (partim) Hall and Clarke, 1895.

Neotremata with phosphatic shells, a listrium, but with no deltidium. Dorsal protegulum usually subcentral.

1. Family TREMATIDÆ Schuchert, 1893.

Primitive Discinacea, in which the posterior margin of the ventral valve has a triangular pedicle notch throughout life. A listrium is usually present.

Discinolepis Waagen, 1885.
Trematis Sharpe, 1847.
Orbicella Hall and Whitfield, 1875 (not d'Orbigny, 1849).
Schizocrania Hall and Whitfield, 1875.
Schizobolus Ulrich, 1886.
Lingulodiscina Whitfield, 1890.
Œhlertella Hall and Clarke, 1890.
? Monobolina Salter, 1865.

2. Family DISCINIDÆ Gray, 1840.

Orbiculidæ McCoy, 1844.

Derived Discinacea with an open pedicle notch in early life in the posterior margin of the ventral valve, which is closed posteriorly during neanic growth, leaving a more or less long, narrow slit partially closed by the listrium.

Orbiculoidea d'Orbigny, 1847.
Schizotreta Kutorga, 1848.
Lindstrœmella Hall and Clarke, 1890.
Rœmerella Hall and Clarke, 1890.
Discina Lamarck, 1819.
Orbicula Sowerby, 1830 (not Cuvier, 1798).
Discinisca Dall, 1871.

Digitized by Google

Superfamily CRANIACEA Waagen, 1885.[1]

Gasteropegmata Waagen, 1885.

Cemented calcareous Neotremata without pedicle or anal openings at maturity.

Family CRANIIDÆ King, 1846.

Orbiculæ Deshayes, 1830; Craniadæ Gray, 1840.

Craniacea with the pedicle functional probably only during nepionic growth.

Crania Retzius, 1781.
- Nummulus Stoeboeus, 1732.
- Ostracites Beuth, 1776.
- Criopus Poli, 1791.
- Criopoderma Poli, 1795.
- Orbicula Cuvier, 1798 (not Sowerby, 1830).
- Orbicularius Duméril, 1806.
- Craniolites Schlotheim, 1820.
- Discina Turton, 1832 (not Lamarck, 1819).
- Criopododerma Agassiz, 1846.
- Choniopora Schauroth, 1854.

Craniella Œhlert, 1888.

Cardinocrania Waagen, 1885.

Ancistrocrania Dall, 1877.
- Cranopsis Dall, 1871 (not A. Adams).

Craniscus Dall, 1871.
- Siphonaria Quenstedt, 1851 (not Sowerby).

Pholidops Hall, 1860.
- Craniops Hall, 1859.

Pseudocrania McCoy, 1851.
- Palæocrania Quenstedt, 1871.

Order PROTREMATA Beecher, 1891.

Derived, articulate Brachiopoda, with the pedicle opening restricted to the ventral valve throughout life or during early growth. Prodeltidium originating on the dorsal side of the body wall in the cephalula stage, and later anchylosed to the ventral shell, thus initiating the development of a deltidium. Pedicle aperture modified by the deltidium. Brachia unsupported by a calcareous skeleton except in the Pentameracea where there are crura.

Superfamily STROPHOMENACEA Schuchert, 1896.[2]

Lineicardines (partim) and Denticardines (partim) Bronn, 1862; Aphaneropegmata (partim), Productacea, Coralliopsida, and Kampylopegmata (partim) Waagen, 1883; Eleutherobranchiata (partim) Neumayr, 1883; Cryptobrachia (partim) Gray, 1848; Thecacea Schuchert, 1893.

Primitive Protremata without spondylia and cruralia.

Family KUTORGINIDÆ Schuchert, 1893.

Primitive Strophomenacea with incipient cardinal areas, great delthyrial opening, and very rudimentary articulating processes and deltidium.

Kutorgina Billings, 1861 (emend Walcott).

?Schizopholis Waagen, 1885.

[1] The writer believes that when the young growth stages of Crania are studied it will be shown that the Craniacea have the superfamily characters of Acrotretacea rather than those of Discinacea.

[2] Text-book of Paleontology, by Zittel and Eastman, 1896, p. 312.

Digitized by Google

? Family EICHWALDIIDÆ Schuchert, 1893.[1]

Primitive or aberrant, rostrate Strophomenacea, with narrow lateral grooves and ridges for articulation. Delthyrium closed by a concave plate (?deltidium). Pedicle emerging through the ventral umbone and moving with growth anteriorly by resorption through the shell, as in Siphonotretidæ.

Eichwaldia Billings, 1858.

Dictyonella Hall, 1867.

1. Family BILLINGSELLIDÆ Schuchert, 1893.

Strophomenacea with well-developed cardinal areas and deltidium. Cardinal process obsolete or very rudimentary. Articulation fairly well developed.

Billingsella Hall and Clarke, 1892.

Protorthis Hall and Clarke, 1892.

2. Family STROPHOMENIDÆ King, 1846.

Strophomenacea with well-developed cardinal areas, deltidium, chilidium, cardinal and articulating processes.

2a. Subfamily RAFINESQUININÆ Schuchert, 1893.

Leptænacea Braun, 1840; Orthisidæ (partim) d'Orbigny, 1847; Davidsonidæ King, 1850; Davidsoninæ Gill, 1871; Strophomeninæ (partim) Gill, 1871; Waagen, 1884; Cadomellinæ Munier-Chalmas, 1887; Leptænidæ Hall and Clarke, 1895.

Strophomenoids with ventral valve convex and dorsal concave, except in Strophonella. The relative form of the valves is the reverse of the Orthothetinæ.

Rafinesquina Hall and Clarke, 1892.

Leptæna Dalman, 1828.
- Leptagonia McCoy, 1844.
- Strophomena Meek, 1873 (not Blainville, 1825).
- Plectambonites Œhlert, 1887 (not Pander, 1830).

Stropheodonta Hall, 1852.
- Brachyprion Shaler, 1865.
- Douvillina Œhlert, 1887.

Leptostrophia Hall and Clarke, 1892.

Pholidostrophia Hall and Clarke, 1892.

Strophonella Hall, 1879.
- Amphistrophia Hall and Clarke, 1892.

Cadomella M.-Chalmas, 1887.

Leptella Hall and Clarke, 1892.

Plectambonites Pander, 1830.
- Leptæna Davidson, 1853; Œhlert, 1877 (not Dalman, 1828).

Leptænisca Beecher, 1890.

Christiania Hall and Clarke, 1892.

Davidsonia Bouchard, 1847.

[1] In 1893 the writer referred this family with doubt to the Rhynchonellacea. The absence of crural plates in Eichwaldia forbids that disposition. If the concave plate closing the umbonal pedicle passage is a deltidium, there can be no doubt that this family belongs to the Protremata. Students should search for the very young of Eichwaldia or Dictyonella, since it is through ontogeny alone that the true systematic position of this family will be determined.

Digitized by Google

2b. Subfamily ORTHOTHETINÆ Waagen, 1884.

Strophomeninæ (partim) Waagen, 1884.

Strophomenoids with the ventral valve convex during early growth, becoming subsequently concave.

? Orthidium Hall and Clarke, 1892.
Strophomena Blainville, 1825.
Hemipronites Meek, 1872 (not Pander, 1830).
Orthothetes Fischer de Waldheim, 1837.
Orthis King, 1850 (not Dalman, 1828).
Hipparionyx Vanuxem, 1842.
Streptorhynchus King, 1850.
Derbya Waagen, 1884.
Kayserella Hall and Clarke, 1892.
Meekella White and St. John, 1870.
Triplecia Hall, 1859.
Dicraniscus Meek, 1872.
Mimulus Barrande, 1879.
Streptis Davidson, 1881.

3. Family THECIDIIDÆ Gray, 1840.

Cemented Strophomenacea in which the interior of the shell is impressed with variously indented brachial furrows.

3a. Subfamily LYTTONIINÆ Waagen, 1883.

Thecidiidæ with the brachial markings common to both valves.

Lyttonia Waagen, 1883.
Leptodus Kayser, 1882.
Oldhamina Waagen, 1883.

3b. Subfamily THECIDIINÆ Dall, 1870.

Thecidiidæ with the brachial markings restricted to the dorsal valve.

Thecidia Defrance, 1822.
Thecidium Sowerby, 1824.
Lacazella M.-Chalmas, 1880.
Thecidiopsis M.-Chalmas, 1887.
Thecidella M.-Chalmas, 1887.
Eudesella M.-Chalmas, 1880.
Pterophloios Gümbel, 1861.
Bactrynium Emmerich, 1855.
(In error. Not Bactrillium Herr.)
Davidsonella M.-Chalmas, 1880.

2aa. Family PRODUCTIDÆ Gray, 1840.

Productina Giebel, 1846.

Strophomenacea with hollow anchoring spines.

2aaa. Subfamily CHONETINÆ Waagen, 1884.

Chonetidæ Bronn, 1862; Hall and Clarke, 1895.

Productidæ with the anchoring spines restricted to the ventral cardinal margin.

Chonetes Fischer de Waldheim, 1837.
Leptæna McCoy, 1844 (not Dalman, 1828).
Anoplia Hall and Clarke, 1892.
Chonetella Waagen, 1884.
Chonostrophia Hall and Clarke, 1892.
Chonetina Krotow, 1888.
Chonetella Krotow, 1884 (not Waagen, 1884).

Digitized by Google

2a^{ab}. Subfamily PRODUCTINÆ Waagen, 1884.

Productidæ with the anchoring spines more or less abundant over the ventral valve and sometimes also over the dorsal valve.

Daviesiella Waagen, 1884.
Productella Hall, 1867.
Productus Sowerby, 1812.
  Pyxis Chemnitz, 1784.
  Producta G. B. Sowerby, 1825.
  Arbusculites Murray, 1831.
  Protonia Linck, 1830 (not Rafinesque).
  Marginifera Waagen, 1884.
Proboscidella Œhlert, 1887.
Etheridgina Œhlert, 1887.
Chonopectus Hall and Clarke, 1892.
Strophalosia King, 1844.
  Orthothrix Geinitz, 1847.
  Leptænalosia King, 1845.
Aulosteges von Helmersen, 1847.
? Aulacorhynchus Dittmar, 1871.
  Isogramma Meek and Worthen, 1873.

2a^{ac}. Family RICHTHOFENIDÆ Waagen, 1885.

Strophomenacea probably derived through the Productidæ, and remarkably modified by ventral cementation. The form of the shell is that of cyathophylloid corals with an operculiform dorsal valve. Shell structure cystose.

Richthofenia Kayser, 1881.

1a. Family ORTHIDÆ Woodward, 1852.

Orthisidæ (partim) d'Orbigny, 1847; Orthinæ and Enteletinæ Waagen, 1884.

Strophomenacea usually with large open delthyria; deltidium only developed in younger growth stages.

Orthis Dalman, 1828.
  Orthambonites Pander, 1830.
Plectorthis Hall and Clarke, 1892.
Hebertella Hall and Clarke, 1892.
Schizophoria King, 1850.
Orthotichia Hall, 1892.
Enteletes Fischer de Waldheim, 1830.
  Syntrielasma Meek, 1865.
Platystrophia King, 1850.
Orthotropia Hall and Clarke, 1895.
Dinorthis Hall and Clarke, 1892.
  Plæsiomys Hall and Clarke, 1892.
Orthostrophia Hall, 1883.
Dalmanella Hall and Clarke, 1892.
Heterorthis Hall and Clarke, 1892.
Bilobites Linné, 1775.
  Dicœlosia King, 1850.
Rhipidomella Œhlert, 1890.
  Rhipidomys Œhlert, 1887 (not Wagner).

Superfamily PENTAMERACEA Schuchert, 1896.[1]

Trullacea Schuchert, 1893; Ancistropegmata (partim) Zittel, 1895; Aphaneropegmata (partim) and Productacea (partim) Waagen, 1883; Eleutherobranchiata (partim) Neumayr, 1883.

Derived Protremata with spondylia to which are attached the adductor, diductor, and ventral pedicle muscles. Commonly cruralia are present.

1. Family CLITAMBONITIDÆ Winchell and Schuchert, 1893.

Orthisidæ (partim) d'Orbigny, 1849; Orthisinæ Waagen, 1884.

Primitive Pentameracea with long, straight cardinal areas and a well-developed deltidium. No cruralium.

[1] Text-book of Paleontology, by Zittel and Eastman, 1896, p. 320.

Digitized by Google

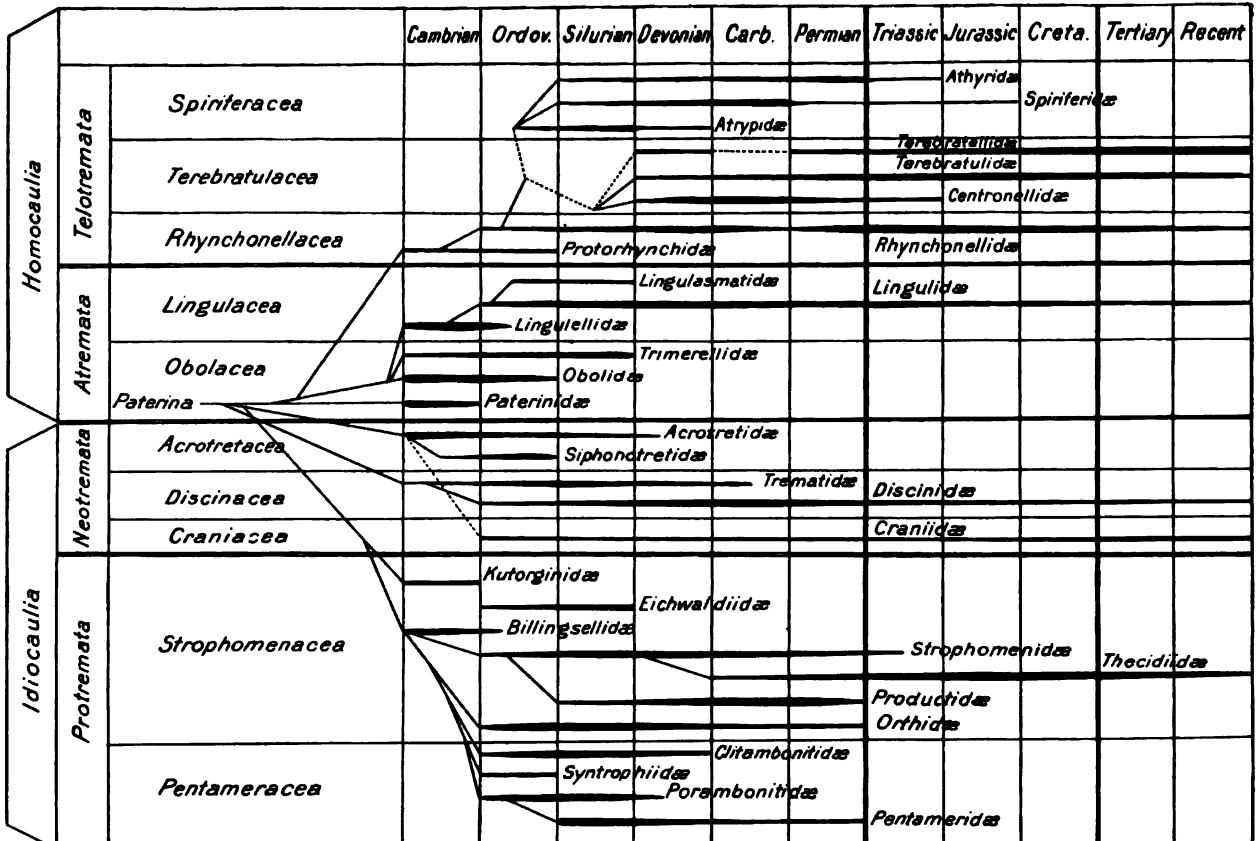


DIAGRAM ILLUSTRATING GEOLOGIC DISTRIBUTION OF FAMILIES.

Digitized by Google

Digitized by Google

Clitambonites Pander, 1830.
Pronites Pander, 1830.
Gonambonites Pander, 1830.
Orthisina d'Orbigny, 1847.
Polytœchia Hall and Clarke, 1892.
Hemipronites Pander, 1830.
Scenidium Hall, 1860.
Mystrophora Kayser, 1871.

2. Family SYNTROPHIIDÆ Schuchert, 1896.[1]

Stricklandiniidæ (partim) Hall and Clarke, 1895.

Primitive Pentameracea with long, straight cardinal areas, deltidia, and cruralia.

Syntrophia Hall and Clarke, 1892–93.

2a. Family PORAMBONITIDÆ Davidson, 1853.[2]

Porambonitinæ Gill, 1871; Porambonitidæ (partim) Nœtling, 1883; Camarellidæ (partim) Hall and Clarke, 1895.

Pentameracea intermediate in structure between the Syntrophiidæ and Pentameridæ, in that the deltidium and the straight cardinal areas of the former family tend to obsolescence, particularly the deltidium. The Porambonitidæ approach the latter family in tending to develop a rostrate shell. Cruralium present.

Camarella Billings, 1859 (emend Hall and Clarke, 1893).
Parastrophia Hall and Clarke, 1893.
Anastrophia Hall, 1867.
Brachymerus Shaler, 1865 (not Dejean, 1834).
Branconia Gagel, 1890.
Porambonites Pander, 1830.
Priambonites Agassiz, 1847.
Isorhynchus King, 1850.
Nœtlingia Hall and Clarke, 1893.
†Lycophoria Lahusen, 1885.

2b. Family PENTAMERIDÆ McCoy, 1844.

Hypothyridæ (partim) King, 1850; Pentameridæ Hall, 1867; Camerophoriinæ Waagen, 1883; Pentamerinæ Gill, 1871; Waagen, 1883; Porambonitidæ (partim) Nœtling, 1883; Stenochismatinæ and Conchidiinæ Œhlert, 1887; Camarellidæ (partim), Stricklandiniidæ (partim), and Amphigenidæ Hall and Clarke, 1895.

Rostrate Pentameracea rarely with straight cardinal areas. Deltidium commonly absent, but sometimes present as a concave plate, being the reverse of the ordinary form of the deltidium and due to the incurved beaks. Cruralium present.

Stricklandinia Billings, 1863.
Stricklandia Billings, 1859.
Pentamerus Sowerby, 1813.
Pentastère Blainville, 1824.
Capellinia Hall and Clarke, 1893.
Pentamerella Hall, 1867.
Gypidula Hall, 1867.
Sieberella Œhlert, 1887.
Camarophorella Hall and Clarke, 1893.
Amphigenia Hall, 1867.
Conchidium Linné, 1753.
Antirhynchonella Quenstedt, 1871.
Zdimir Barrande, 1879.
Gypidia Dalman, 1828.
Clorinda Barrande, 1879.
Barrandella Hall and Clarke, 1893.
Enantiosphen Widborne (Holzapfel), 1893.
Camarophoria King, 1846.
Stenochisma Dall, 1877; Œhlert, 1887 (not Conrad, 1839).

[1] Text book of Paleontology, by Zittel and Eastman, 1896, p. 320.

[2] Since Hall and Clarke's family Camarellidæ (1895), after removing Camarophoria and Camarophorella, is based upon the same family characters as those of the Porambonitidæ (1853), as Porambonites is now interpreted, Davidson's family is retained on the ground of priority.

Digitized by Google

Synopsis of the divisions of Brachiopoda higher than genera.

Superorders.	*Orders.*	*Superfamilies.*	*Families.*	
Pedicle common to both valves throughout life or only in youthful growth. (Homocaulia.)	Pedicle opening common to both valves throughout life. No deltidial plates. Inarticulate. (Atremata.)	Shells rounded. Pedicle short. Animal not burrowing. (Obolacea.)	Valves semicircular; pedicle opening more or less large	= Paterinidæ.
			Valves rounded, posteriorly acuminate; pedicle opening small	= Obolidæ.
			Valves round or oval, thick, with solid or excavated platforms	= Trimerellidæ.
		Shells elongate. Pedicle long. Animal burrowing. (Lingulacea.)	Shells thin, elongate, with oboloid interiors	= Lingulellidæ.
			Shells thin, elongate, with muscular system highly specialized	= Lingulidæ.
			Shells elongate, with solid platforms	= Lingulasmatidæ.
	Pedicle opening common to both valves only in youthful growth. Deltidial plates usually present. (Telotremata.)	Brachia supported by crura. (Rostracea.)	Shells primitive. No deltidial plates; articulation rudimentary	= Protorhynchidæ.
			Articulation and deltidial plates well developed	= Rhynchonellidæ.
		Brachia supported by loops. (Terebratulacea.)	Loops free, developing direct; no metamorphoses	= Centronellidæ.
			Loops free, developing indirect	= Terebratulidæ.
			Loops attached to a median septum; developing indirect	= Terebratellidæ.
		Brachia supported by spiralia. (Spiriferacea.)	Crura directly continuous with bases of primary lamellæ between which are the spiralia	= Atrypidæ.
			Crura directly continuous with bases of primary lamellæ which are between the spiralia	= Spiriferidæ.
			Bases of primary lamellæ between the spiralia, and sharply recurving dorsally at their junction with the crura	= Athyridæ.

Digitized by Google

Synopsis of the divisions of Brachiopoda higher than genera—Continued.

Superorders.	*Orders.*	*Superfamilies.*	*Families.*	
Pedicle restricted to ventral valve throughout or only in youthful growth. (Idiocaulia.)	Pedicle restricted to ventral valve throughout life. Inarticulate. (Neotremata.)	Pedicle aperture modified by a deltidium. (Acrotretacea.)	Pedicle opening small, circular, posterior to protegulum	= Acrotretidæ.
			Pedicle fissure narrow, elongate, anterior to protegulum	= Siphonotretidæ.
		Pedicle slit modified by a listrium. (Discinacea.)	Pedicle fissure marginal, open posteriorly	= Trematidæ.
			Pedicle fissure narrow, elongate, closed posteriorly	= Discinidæ.
		Pedicle suppressed. (Craniacea.)	Shells partially or completely cemented to foreign bodies	= Craniidæ.
	Pedicle restricted to ventral valve throughout or a portion of life. Articulate. (Protremata.)	Shells without spondylia and cruralia. (Strophomenacea.)	Pedicle opening large; deltidium and articulation incipient. No crural process	= Kutorginidæ.
			Rostrate, aberrant Strophomenacea	= Eichwaldiidæ.
			Cardinal areas and deltidium well developed. No cardinal process	= Billingsellidæ.
			Cardinal areas, deltidium, chilidium, and cardinal process well developed	= Strophomenidæ.
			Strophomenidæ with impressed brachial furrows	= Thecidiidæ.
			Valves more or less covered with hollow, anchoring spines	= Productidæ.
			Cone-shaped productoids completely modified by cementation	= Richthofenidæ.
			Delthyrium usually large, open; deltidium developed only in early growth	= Orthidæ.
		Shells with spondylia and cruralia. (Pentameracea.)	Large, straight cardinal areas with prominent deltidium. No cruralia	= Clitambonitidæ.
			Straight cardinal areas, prominent deltidium, and short cruralia	= Syntrophiidæ.
			Shells intermediate in structure between Syntrophiidæ and Pentameridæ	= Porambonitidæ.
			Shells rostrate, commonly without deltidium. Cruralia well developed	= Pentameridæ.

Digitized by Google

CHAPTER VI.

INDEX AND BIBLIOGRAPHY OF AMERICAN FOSSIL BRACHIOPODA.

ACAMBONA White. Genotype A. prima White.

Acambona White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 27, figs. 1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 119; —Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 797.

Acambona osagensis (Swallow). Chouteau (L. Carb.).

Retzia osagensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 653.

Acambona? osagensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 120, pl. 51, figs. 38, 39.

Retzia? osagensis Keyes, Geol. Survey Missouri, V, 1895, p. 94.

Loc. Cooper and Benton counties, Missouri.

Acambona prima White. Burlington (L. Carb.).

Acambona prima White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 27, figs. 1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 119, pl. 51, figs. 40, 41.

Eumetria prima Miller, North American Geol. and Pal., 1889, p. 346.

Loc. Burlington, Iowa.

Obs. It is probable that this species is identical with A. osagensis.

ACROTHELE Linnarsson. Genotype A. coriacea Linnarsson.

Acrothele Linnarsson, Bihang till Kgl. Svenska Vetens.-Akad. Handl., III, 1876, p. 20.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 107.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 98, 167;—Eleventh Ann. Rep. N. Y. State Geologist, 1892, p. 249.

Acrothele bellula Walcott. Middle Cambrian.

Acrothele bellula Walcott, Proc. U. S. National Mus., XIX, 1897, p. 716, pl. 60, figs. 4–4e.

Loc. Cowans Creek, Cherokee County, Alabama.

Acrothele decipiens Walcott. Lower Cambrian.

Acrothele decipiens Walcott, Proc. U. S. National Mus., XIX, 1897, p. 716, pl. 60, fig. 2.

Loc. Near Stoner's, York County, Pennsylvania.

Acrothele (?) dichotoma Walcott. Lower Cambrian.

Acrothele? dichtoma Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 14, pl. 9, fig. 11;—Bull. U. S. Geol. Survey, 30, 1886, p. 107.

Loc. Eureka district, Nevada.

Acrothele matthewi (Hartt). Middle Cambrian.

Lingula matthewi Hartt, Dawson's Acadian Geology, 2d ed., 1868, p. 644, fig. 221;—Ibidem, 3d ed., 1874, p. 644, fig. 221.

Acrothele matthewi Matthew, Trans. Royal Soc. Canada, III, 1886, p. 39, pl. 5, fig. 15.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 99, pl. 3, fig. 29.—Matthew, Trans. N. Y. Acad. Sci., XIV, 1895, p. 128, pl. 5, figs. 6, 7, 8.

Loc. Portland, New Brunswick; Manuels Brook, Conception Bay, Newfoundland.

Digitized by Google

Acrothele matthewi costata Matthew. ?Middle Cambrian.

Acrothele matthewi var. costata Matthew, Trans. N. Y. Acad. Sci., XIV, 1895, p. 128, pl. 5, fig. 9.

Loc. Hanford Brook, New Brunswick.

Acrothele matthewi lata Matthew. Middle Cambrian.

Acrothele matthewi var. lata Matthew, Trans. Royal Soc. Canada, III, 1886, p. 41, pl. 5, fig. 17.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 3, figs. 26–28.

Loc. Portland, New Brunswick.

Acrothele matthewi prima Matthew. Middle Cambrian.

Acrothele matthewi var. prima Matthew, Trans. Royal Soc. Canada, III, 1886, p. 41, pl. 5, fig. 16.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 3, fig. 25.

Loc. Hanford Brook, New Brunswick.

Acrothele subsidua (White). Lower and Middle Cambrian.

Acrotreta? subsidua White, Wheeler's Geogr. Geol. Expl. and Surv. west 100 Merid., Prelim. Rep., 1874, p. 6;—Ibidem, Final Rep., IV, 1875, p. 34, pl. 1, fig. 3.

Acrothele subsidua White, Proc. U. S. National Mus., III, 1880, p. 47.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 108, pl. 9, fig. 4;—Tenth. Ann. Rep. U. S. Geol. Survey, 1891, p. 608, pl. 70, fig. 1.—Beecher, American Jour. Sci., XLI, 1891, p. 357, pl. 17, fig. 12.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 100, pl. 3, figs. 30, 31.

Loc. Antelope Spring, Utah; Pioche, Nevada.

ACROTRETA Kutorga. Genotype A. subconica Kutorga.

Acrotreta Kutorga, Verhand. Kais. Min. Gessel. zu St. Petersburg, 1848, p. 275.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 16.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 101, 166;—Eleventh Ann. Rep. N. Y. State Geologist, 1892, p. 250.

Acrotreta attenuata Meek=A. gemma.

Acrotreta baileyi Matthew. Middle and Upper Cambrian.

Acrotreta baileyi Matthew, Trans. Royal Soc. Canada, III, 1886, p. 36, pl. 5, fig. 13.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 102, pl. 3, figs. 32–34.—Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 43, pl. 12, fig. 7d.

Loc. Hanford Brook and Long Reach, New Brunswick.

Acrotreta gemma Billings. Lower to Upper Cambrian.

Acrotreta gemma Billings, Pal. Fossils, I, 1865, p. 216, fig. 201.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 17, pl. 1, fig. 1; pl. 9, fig. 9;—Bull. U. S. Geol. Survey, 30, 1886, p. 98, pl. 8, fig. 1;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 608, pl. 67, fig. 5.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 102, figs. 55–57.—Matthew, Trans. N. Y. Acad. Sci., XIV, 1895, p. 126.

Acrotreta subconica Meek, Hayden's Sixth Ann. Rep. U. S. Geol. Survey Terr., 1873, p. 463.

Acrotreta attenuata Meek, Ibidem, 1873, p. 463.

Acrotreta pyxidicula White, Wheeler's Geogr. Geol. Expl. and Survey west 100 Merid., Prelim. Rep., 1874, p. 9;—Ibidem, Final Rep., IV, 1875, p. 53, pl. 3, fig. 3.

Loc. Near Portland Creek, Newfoundland; Eureka and White Pine mining districts, Nevada.

Acrotreta gemma depressa Walcott. Middle Cambrian.

Acrotreta gemma var. depressa Walcott, Proc. U. S. National Mus., XI, 1888, p. 441.

Loc. Mount Stephen, British Columbia.

Digitized by Google

Acrotreta gemmula Matthew. Middle Cambrian.

Acrotreta gemmula Matthew, Trans. Royal Soc. Canada, X, 1894, p. 87, pl. 16, fig. 2;—Trans. N. Y. Acad. Sci., XIV, 1895, p. 126, pl. 5, fig. 5.

Loc. St. Martins, New Brunswick.

Acrotreta gulielmi Matthew=Discinopsis gulielmi.

Acrotreta microscopica (Shumard). Middle Cambrian.

Discina microscopica Shumard, American Jour. Sci., XXXII, 2d ser., 1861, p. 221.

Loc. Occurs abundantly in Burnett and Llano counties, Texas.

Acrotreta pyxidicula White=Acrotreta gemma.

Acrotreta subconica Meek (non Kutorga)=Acrotreta gemma.

Acrotreta (?) subsidua White=Acrothele subsidua.

Ægilops Hall. A genus of pelecypods.

AMBOCŒLIA Hall. Genotype Orthis umbonata Conrad.

Ambocœlia Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 71, figs. 1-3; p. 72, figs. 4-6.—Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., 172, 1864, p. 20.—Hall, Pal. New York, IV, 1867, p. 258—Davidson, Suppl. British Sil. Brach., Palæontographical Soc., 1882, p. 131.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 85.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 54;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 761.

Ambocœlia fimbriata Claypole. Portage (Dev.).

Ambocœlia fimbriata Claypole, Proc. American Phil. Soc., XXI, 1883, p. 232.

Loc. Perry County, Pennsylvania.

Ambocœlia gemmula McChesney=Ambocœlia planoconvexa.

Ambocœlia gregaria Hall. Chemung (Dev.).

Orthis unguiculus Hall (non Phillips), Geol. New York; Rep. Fourth Dist., 1843, p. 267, fig. 5.

Ambocœlia gregaria Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 81;—Fifteenth Rep. Ibidem, 1862, p. 186.—Williams, Bull. U. S. Geol. Survey, 3, 1884, p. 11.

Ambocœlia umbonata var. gregaria Hall, Pal. New York, IV, 1867, p. 261, pl. 44, figs. 19-25.

Loc. New York; Pennsylvania, and Virginia.

Obs. See Martinia subumbona.

Ambocœlia minuta White. Kinderhook (L. Carb.).

Ambocœlia (Spirifer?) minuta White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 26.

Loc. Hamburg, Illinois, and Hannibal, Missouri.

Ambocœlia planoconvexa (Shumard). Upper Carboniferous.

Spirifer planoconvexa Shumard, Geol. Rep. Missouri, 1855, p. 202.—Geinitz, Carbon u. Dyas in Nebraska, 1866, p. 42, pl. 3, figs. 10-18.

Ambocœlia gemmula McChesney, New Pal. Fossils, 1860, p. 41;—Ibidem, 1865, pl. 1, fig. 3.

Spirifer (Martinia) planoconvexa Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., 172, Pt. I, 1864, p. 20, figs. a-e.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 184, pl. 4, fig. 4; pl. 8, fig. 2.

Martinia planoconvexa McChesney, Trans. Chicago Acad. Sci., I, 1868, p. 34, pl. 1, fig. 3.

Digitized by Google

Amboccelia planoconvexa (Shumard)—Continued.

Spirifera (Martinia) planoconvexa Derby, Bull. Cornell Univ., I, 1874, p. 19, pl. 8, figs. 12, 16, 18; pl. 9, fig. 7.—White, Wheeler's Geogr. Geol. Expl. and Survey west 100 Merid., IV, 1875, p. 135, pl. 10, fig. 3;—Thirteenth Rep. Indiana State Geol., 1884, p. 134, pl. 32, figs. 23, 24.—Herrick, Bull. Denison Univ., II, 1887, p. 46, pl. 1, fig. 12.—Keyes, Geol. Survey Missouri, V, 1895, p. 85.

Amboccelia planoconvexa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 56, pl. 39, figs. 10–15.

Loc. Missouri; Iowa; Illinois; Ohio; Indiana; Kansas; Nebraska; New Mexico; Elko Mountain, Nevada; Bomjardim and Itaituba, Brazil.

Amboccelia præumbona Hall. Hamilton (Dev.).

Orthis præumbona Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 167.

Amboccelia præumbona Hall, Thirteenth Rep. Ibidem, 1860, p. 71;—Pal. New York, IV, 1867, p. 262, pl. 44, figs. 1–6.

Loc. Seneca, Cayuga, and Canandaigua lakes, New York.

Amboccelia spinosa Hall and Clarke. Hamilton (Dev.).

Amboccelia spinosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. 56, 363, pl. 39, figs. 16–18.—Clarke, Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 177, pl. 4, figs. 6–8.

Loc. Livingston County, New York.

Amboccelia subumbona Hall=Martinia subumbona.

Amboccelia umbonata (Conrad). Marcellus–Chemung (Dev.).

Orthis umbonata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 264, pl. 14, fig. 4.—Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 167, figs. 1–3.

Orthis nucleus Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 180, fig. 8.

Amboccelia umbonata Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 71;—Pal. New York, IV, 1867, p. 259, pl. 44, figs. 7–18.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 86, pl. 17, figs. 25, 26.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pl. 29, fig. 17; pl. 39, figs. 4–9.

Martinia umbonata Herrick, Geol. Ohio, VII, 1895, pl. 20, fig. 3.

Loc. New York; Pennsylvania; Falls of Ohio.

Amboccelia umbonata gregaria Hall=Amboccelia gregaria.

AMPHIGENIA Hall. Genotype Pentamerus elongatus Vanuxem.

Amphigenia Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 163;—Pal. New York, IV, 1867, pp. 374, 382.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 252;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 848.

Amphigenia curta (Meek and Worthen). Oriskany (Dev.).

Stricklandinia elongata var. curta Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 402, pl. 8, fig. 1; pl. 9, fig. 5.—? Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 254.

Loc. Union County, Illinois.

Amphigenia elongata (Vanuxem). Oriskany and Up. Helderberg (Dev.).

Pentamerus elongatus Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 132, fig. 1.—Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, Tables of Organic Remains.

Meganteris elongatus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 123, figs. 1, 2.

Rensselæria elongata Hall, Twelfth Rep. Ibidem, 1859, p. 38;—Pal. New York, III, 1859, p. 453.

Stricklandia elongata Billings, Canadian Jour., VI, 1861, p. 267, figs. 91, 92.

Digitized by Google

Amphigenia elongata (Vanuxem)—Continued.

Stricklandinia elongata Billings, Geol. Canada, 1863, p. 371, fig. 390.

Amphigenia elongata Hall, Pal. New York, IV, 1867, p. 383, pl. 58A, figs. 21–24; pl. 59, figs. 1–11.—Billings, Canadian Nat. Geol., n. ser., VII., 1874, p. 240.—Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 34.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 253, pl. 73, figs. 16–20; pl. 74, figs. 1–9; pl. 76, fig. 9.

Loc. New York; Michigan; Cayuga, Ontario; Rio Maecuru and Rio Curua, Brazil.

Amphigenia elongata subtrigonalis Hall. Up. Helderberg (Dev.).

Meganteris subtrigonalis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 123.

Amphigenia elongata var. subtrigonalis Hall, Pal. New York, IV, 1867, p. 384.

Loc. Erie County, New York.

Amphigenia elongata undulata Hall. Up. Helderberg (Dev.).

Amphigenia elongata var. undulata Hall, Pal. New York, IV, 1867, p. 384, pl. 58A, figs. 25–27.

Loc. Mackinac, Michigan.

AMPHISTROPHIA Hall and Clarke. Genotype Strophonella striata Hall.

Amphistrophia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 292;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 283.

Obs. Proposed as a subgenus of Strophonella.

ANABAIA Clarke. Genotype A. paraia Clarke.

Anabaia Clarke, Pal. New York, VIII, Pt. II, 1893, p. 141.—Hall and Clarke, Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 805.

Anabaia paraia Clarke. Silurian.

Anabaia paraia Clarke, Pal. New York, VIII, Pt. II, 1893, p. 141, figs. 124–127.

Loc. Rio Trombetas, Province of Para, Brazil.

ANASTROPHIA Hall. Genotype Pentamerus verneuili Hall.

Brachymerus Shaler (non Dej., 1834), Bull. Mus. Comp. Zool., 4, 1865, p. 69.

Anastrophia Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 163;—Pal. New York, IV, 1867, p. 374.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 47.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 224;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 839.

Anastrophia brevirostris (Sowerby?) Hall. Niagara (Sil.).

Terebratula brevirostris Sowerby, Murchison's Sil. System, 1839, p. 631, pl. 13, fig. 15.

Atrypa brevirostris? Hall, Pal. New York, II, 1852, p. 278, pl. 58, fig. 1.

Pentamerus brevirostris Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 77.

Rhynchonella brevirostris Billings, Geol. Canada, 1863, p. 315, fig. 324.

Loc. Lockport, New York.

Obs. Compare with Anastrophia interplicata. If a pentameroid, this species is probably identical with Anastrophia interplicata Hall.

Anastrophia hemiplicata W. and S.=Parastrophia hemiplicata.

Anastrophia internascens Hall. Niagara (Sil.).

Anastrophia verneuili Hall (non Hall, 1859), Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., Doc. ed., 1876, pl. 26, figs. 41–49.

Anastrophia internascens Hall, Ibidem, 1879, p. 168, pl. 26, figs. 41–49;—Eleventh Rep. State Geol. Indiana, 1882, p. 311, pl. 26, figs. 41–49.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 47, pl. 32, figs. 17–20.—Beecher and Clarke, Mem. N. Y. State Mus., 1, 1889, p. 32, pl. 3, figs. 14–16.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 224, pl. 63, fig. 30.

Loc. Waldron, Indiana; Louisville, Kentucky; Milwaukee, Wisconsin.

Digitized by Google

Anastrophia interplicata (Hall). **Niagara (Sil.).**

Atrypa interplicata Hall, Pal. New York, II, 1852, p. 275, pl. 57, fig. 2.

Pentamerus interplicatus Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 77.

Anastrophia interplicata Miller, American Pal. Fossils, 1877, p. 104.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 224.

Loc. Lockport, New York; Louisville, Kentucky; Wisconsin.

Obs. See A. brevirostris.

Anastrophia reversa Miller=Parastrophia reversa.

Anastrophia scofieldi W. and S.=Parastrophia scofieldi.

Anastrophia verneuili Hall, 1876 (non 1859)=Anastrophia internascens.

Anastrophia verneuili (Hall). **Lower Helderberg (Dev.).**

Atrypa lacunosa Vanuxem (non Sowerby), Geol. N. Y.; Rep. Third Dist., 1842, p. 117, fig. 3, and p. 119.

Pentamerus verneuili Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 104, figs. 1, 2;—Pal. New York, III, 1859, p. 260, pl. 48, fig. 1.—Billings, Geol. Canada, 1863, p. 957, fig. 453.

Anastrophia verneuili Miller, N. American Geol. Pal., 1889, p. 334.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 224, pl. 63, figs. 31–38; pl. 84, figs. 43, 44.

Loc. Eastern New York; Perry County, Tennessee; Petermann Fiord, Greenland.

Anazyga recurvirostra Davidson=Zygospira recurvirostris.

ANOPLIA Hall and Clarke. **Genotype Leptæna nucleata Hall.**

Anoplia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 309;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 293.

Anoplia nucleata Hall. **Oriskany and Corniferous (Dev.).**

Leptæna nucleata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 47.

Leptæna? nucleata Hall, Pal. New York, III, 1859, p. 419, pl. 94, fig. 1.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 393, pl. 8, fig. 8.

Anoplia nucleata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 309, pl. 15A, figs. 17, 18; pl. 20, figs. 14–17.

Loc. Albany County, New York; Alexander County, Illinois; Cayuga, Ontario.

Obs. It is probable that Productella nucleata Nicholson is a synonym of this species.

ANOPLOTHECA Sandberger (emend Hall and Clarke). Genotype Productus lamellosus Sandberger=Terebratula venusta Schnur.

Anoplotheca F. Sandberger, Sitzb. d. k. k. Akad. d. Wissens., math -naturw. Classe, XVI, 1853, p. 5; XVIII, p. 102.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 129, figs. 113–121.

Leptocœlia Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 108;—Twelfth Rep., Ibidem, 1859, p. 32, figs. 1, 2, 4;—Pal. New York, III, 1859, p. 447.—Billings, Canadian Jour., VI, 1861, p. 351.—Hall, American Jour. Sci., XXXVI, 1863, p. 14.—Rominger, American Jour. Sci., XXXV, 1863, p. 84.—Hall, Pal. New York, IV, 1867, p. 365.—Dall, American Jour. Conch., VII, 1871, p. 60.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 151.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 136.

Cœlospira Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 59;—Trans. Albany Institute, IV, 1863, p. 146;—Pal. New York, IV, 1867, p. 328.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 134, figs. 122, 123.

Bifida Davidson, Supplement to British Dev. Brach., Palæontographical Soc., 1882, p. 27.

Anoplotheca, Cœlospira, and Leptocœlia Hall and Clarke, Thirteenth Ann. Rep. N. Y. State Geologist, 1895, pp. 801–803.

Digitized by Google

ANOPLOTHECA Sandberger (emend Hall)—Continued.

Obs. Hall and Clarke have shown that Anoplotheca and Bifida are synonymous terms and that Cœlospira is also structurally identical. The latter name, however, they retain as a subgenus of Anoplotheca. While the brachydium is not yet fully known in Leptocœlia, all its other characters are the same as those of Cœlospira. Under these circumstances it appears best, for the present at least, to refer all American species of Leptocœlia and Cœlospira to Anoplotheca.

Anoplotheca acutiplicata (Conrad). Corniferous (Dev.).

Atrypa acutiplicata Conrad, Fifth Ann. Rep. N. Y. Geol. Survey, 1841, p. 54.—Hall, Fifteenth Rep. N. Y. State Cab. Nat. Hist., 1862, pl. 11, fig. 17.

Leptocœlia acutiplicata Hall, Pal. New York, IV, 1867, p. 365, pl. 67, figs. 30–39.

Cœlospira acutiplicata Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 136, pl. 53, figs. 32–39.

Loc. Waterville, Cassville, East Victor, etc., New York.

Anoplotheca camilla (Hall). Oriskany and Up. Helderberg (Dev.).

Cœlospira concava Hall (non Hall 1863), Pal. New York, IV, 1867, p. 329.

Cœlospira camilla Hall, Ibidem, 1867, pl. 52, figs. 13–19;—Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 168.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 136, pl. 53, figs. 24–31.

Loc. Caledonia, New York; county of Haldimand, Ontario.

Anoplotheca concava (Hall). Lower Helderberg (Dev.).

Leptocœlia concava Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 107;—Pal. New York, III, 1859, p. 245, pl. 38, figs. 1–7.—Billings, Canadian Jour., VI, 1861, p. 352, fig. 127;—Geology Canada, 1863, p. 369, fig. 383; p. 957, fig. 451.

Cœlospira concava Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 60;—Trans. Albany Institute, IV, 1863, p. 146.—Meek, American Jour. Sci., 2d ser., XL, 1865, p. 33.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 134, figs. 122, 123; pl. 53, figs. 20–23.

Loc. Albany and Schoharie counties, New York; Kennedy Channel, Arctic region.

Anoplotheca dichotoma (Hall). Oriskany (Dev.).

Leptocœlia dichotoma Hall, Pal. New York, III, 1859, p. 452, pl. 103B, figs. 3.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 137.

Loc. Cumberland, Maryland.

Obs. Possibly the young of Anoplotheca fiabellites.

Anoplotheca fimbriata (Hall). Oriskany (Dev.).

Leptocœlia fimbriata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 83, fig. 3;—Pal. New York, III, 1859, p. 450, pl. 103B, fig. 2.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 137, pl. 53, figs. 47–52, 54, 55.

Loc. Cumberland, Maryland.

Anoplotheca fiabellites (Conrad). Oriskany and Corniferous (Dev.).

Atrypa fiabellites Conrad, Fifth Ann. Rep. N. Y. Geol. Survey, 1841, p. 55.

Atrypa palmata Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 276, pl. 10, fig. 5.

Orthis palmata Sharpe and Salter, Trans. Geol. Soc. London, 2d ser., VII, 1856, p. 207, pl. 26, figs. 7–10.

Leptocœlia propria Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 108.

Leptocœlia fiabellites Hall, Twelfth Rep. Ibidem, 1859, p. 33, figs. 1, 2, 4;—Pal. New York, III, 1859, p. 449, pl. 103B, fig. 1; pl. 106, fig. 1.—Billings, Canadian Jour., VI, 1861, p. 351, fig. 126;—Geology Canada, 1863, p. 369, fig. 382.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 397, pl. 8, fig. 3.—Billings, Pal. Fossils, II, 1874, p. 42, pl. 3, figs. 5, 6.—Steinmann, American Naturalist, XXV, 1891, p. 856.—A. Ulrich, N. Jahrb. f. Mineral., Beilageband,

Digitized by Google

Anoplotheca flabellites (Conrad)—Continued.

VIII, 1892, p. 60, pl. 4, figs. 9, 10–13.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 137, pl. 53, figs. 40–46, 53.—Von Ammon, Zeits. Gesells. für Erdk., Berlin, XXVIII, 1893, p. 363, fig. 7.

Orthis aymara Salter, Quart. Jour. Geol. Soc. London, XVII, 1861, p. 68, pl. 4, fig. 14.

Orthis palmata Sharpe and Salter, Trans. Geol. Soc. London, 2d ser., VII, 1856, p. 207, pl. 26, figs. 7–10.

Loc. Schoharie, etc., New York; county of Haldimand, Ontario; Gaspé; Cumberland, Maryland; Union County, Illinois; Bolivia; Tanquarassu, Matto Grosso, Brazil; Falkland Islands; South Africa.

Anoplotheca hemispherica (Sowerby). Clinton (Sil.).

Atrypa hemispherica Sowerby, Murchison's Silurian System, 1839, p. 639, pl. 20, fig. 7.—Hall, Pal. New York, II, 1852, p. 74, pl. 23, fig. 10.—Billings, Geology Canada, 1863, p. 318, fig. 337.

Atrypa hemispherica? Hall, Geology, N. Y.; Rep. Fourth Dist., 1843, p. 73, fig. 4.

Leptocœlia hemispherica Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 77.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 152, pl. 32, figs. 21–23, 36–39.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 325, pl. 6, figs. 18, 19.

Atrypa flabella Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 68.

Cœlospira? hemispherica Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 136, pl. 82, figs. 1–4 (? pl. 52, fig. 16).

Loc. England; Rochester, Sodus, and Walcott, New York; Louisville, Kentucky; Cumberland Gap, Tennessee; Ringgold, Georgia; Collinsville, Alabama; Arissig, Nova Scotia (Ami); Anticosti.

Anoplotheca infrequens (Walcott). Lower and Upper Devonian.

Trematospira infrequens Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 151, pl. 4, fig. 3.

Loc. Lone Mountain, Nevada.

Obs. The exterior is like that of A. flabellites.

Anoplotheca planoconvexa (Hall). Clinton (Sil.).

Atrypa planoconvexa Hall, Pal. New York, II, 1852, p. 75, pl. 23, fig. 11.—Billings, Geology Canada, 1863, p. 318, fig. 336.

Leptocœlia planoconvexa Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.—Nicholson and Hinde, Canadian Jour., n. ser., XIV, 1874, p. 144.

Cœlospira ?planoconvexa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 136, pl. 52, fig. 15; pl. 53, figs. 11–16.

Loc. Flamborough Head, Ontario; Niagara of Wisconsin (Whitfield).

Anoplotheca plicatula (Hall). Clinton (Sil.).

Atrypa plicatula Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 71, fig. 4;—Pal. New York, II, 1852, p. 74, pl. 23, fig. 9.

Leptocœlia? plicatula Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.

Rhynchonella plicata Miller, N. American Geol. Pal., 1889, p. 369.

Cœlospira? plicatula Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 136, pl. 52, figs. 12–14; pl. 82, fig. 5.

Loc. Reynales Basin, New York; Niagara of Wisconsin (Whitfield).

ATHYRIS McCoy (emend Hall and Clarke).

Genotype Terebratula concentrica von Buch.

Athyris McCoy, Carb. Fossils Ireland, 1844, pp. 128, 146.—Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 73.—Billings, Canadian Jour., V, 1860,

Digitized by Google

ATHYRIS McCoy (emend Hall and Clarke)—Continued.

p. 273;—Ibidem, VI, 1861, p. 138;—Pal. Fossils, I, 1862, p. 144.—Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, pp. 152, 258;—Pal. New York, IV, 1867, p. 282.—Billings, American Jour. Sci., XLIV, 1867, p. 48.—Herrick, Bull. Denison Univ., IV, 1888, p. 14.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 87.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 83, fig. 57 on p. 86;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 777.

Spirigera d'Orbigny, Paris Acad. Sci., Comptes Rendus, XXV, 1847, p. 268.

Euthyris Quenstedt, Petrefactenkunde Deutschlands, 1871, p. 442.

Athyris americana Swallow=Cleiothyris roissyi.

Athyris angelica Hall. Chemung (Dev.).

Athyris angelica Hall, Fourteenth Rep. N. Y. State Cab. Nat. Hist., 1861, p. 99;—Fifteenth Rep. Ibidem, 1862, pl. 3, figs. 10–13, 24;—Pal. New York, IV, 1867, p. 292, pl. 47, figs. 9–20.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 148.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 90, pl. 45, figs. 26–30.

Loc. Phillipsburg, Rockville, etc., New York; Meadville, Pennsylvania; Eureka district, Nevada.

Athyris angelica occidentalis Whiteaves. Hamilton (Dev.).

Athyris angelica occidentalis Whiteaves, Cont. Canadian Pal., I, 1891, p. 227, pl. 32, fig. 3.

Loc. Athabasca River, Canada.

Athyris ashlandensis Herrick=A. lamellosa.

Athyris biloba (A. Winchell). Kinderhook (L. Carb.).

Spirigera biloba A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 118.

Loc. Rockford, Indiana.

Obs. This species is not well established and is based upon a single ventral valve.

Athyris blancha Billings=Meristella blancha.

Athyris borealis Billings=Catazyga erratica.

Athyris brittsi Miller. Middle Devonian.

Athyris brittsi Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 314, pl. 9, figs. 16–18.

Loc. Near Otterville, Missouri.

Obs. Probably the same as A. spiriferoides.

Athyris caputserpentis Swallow=Seminula caputserpentis.

Athyris charitonensis Swallow=Seminula charitonensis.

Athyris chloe Billings=Parazyga hirsuta.

Athyris clara Billings=Meristella nasuta.

Athyris claytoni Swallow=Seminula claytoni.

Athyris clintonensis Swallow=Cleiothyris clintonensis.

Athyris clusia Billings=Meristella clusia.

Athyris concentrica Billings (non von Buch)=A. spiriferoides.

Athyris congesta Conrad=Hyatella congesta.

Athyris cora Hall. Hamilton and Chemung ? (Dev.).

Athyris cora Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 94;—Fifteenth Rep. Ibidem, 1862, pl. 3, figs. 15, 16;—Pal. New York, IV, 1867, p. 291, pl. 47, figs. 1–7.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 90, pl. 45, figs. 6–10.

Loc. Delphi, New York.

Digitized by Google

Athyris (?) corpulenta (A. Winchell). Kinderhook (L. Carb.).

Spirigera corpulenta A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 6.

Loc. Burlington, Iowa.

Athyris crassicardinalis White=Cleiothyris crassicardinalis.

Athyris crassirostra Billings=Whitfieldella cylindrica.

Athyris cylindrica Billings=Whitfieldella cylindrica.

Athyris densa Hall and Clarke. St. Louis (L. Carb.).

Athyris densa Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 364, pl. 46, figs. 6–12.

Loc. Washington County, Indiana; Colesburg, Kentucky.

Obs. Compare with Centronella (?) crassicardinalis.

Athyris differentis McChesney=Seminula argentea.

Athyris eborea A. Winchell=A. vittata.

Athyris euzona Swallow=Seminula formosa.

Athyris(?) formosa Swallow=Seminula formosa.

Athyris fultonensis (Swallow). Corniferous and Hamilton (Dev.).

Spirigera fultonensis Swallow, Trans. St. Louis Acad. Sci., I, July or August, 1860, p. 650.

Spirigera minima Swallow, Ibidem, 1860, p. 649.

Athyris vittata Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 89;—Pal. New York, IV, 1867, p. 289, pl. 46, figs. 1–4.—White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, p. 502, pl. 4, figs. 8, 9;—Tenth Rep. State Geol. Indiana, 1881, p. 134, pl. 4, figs. 8, 9.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 87, pl. 16, figs. 25–32.—Whiteaves, Cont. Canadian Pal., I, 1892, p. 228.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 90, figs. 62, 63; pl. 45, figs. 1–5.—Keyes, Geol. Survey Missouri, V, 1895, p. 90, pl. 41, fig. 1.

Spirigera eborea A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 94.

Loc. Callaway County, Missouri; Iowa City and New Buffalo, Iowa; Falls of Ohio; Alpena, Michigan; Lake Winnipegosis, Manitoba.

Obs. Specimens of S. fultonensis Swallow and S. eborea Winchell in the writer's collection prove to be the same as A. vittata Hall.

Athyris hannibalensis (Swallow). Chouteau (L. Carb.).

Spirigera hannibalensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 649.

Athyris hannibalensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 90, pl. 46, figs. 13–15.—Keyes, Geol. Survey Missouri, V, 1895, p. 90, pl. 40, fig. 9.

Loc. Clarksville, Hannibal, etc., Missouri; Sciotoville, Ohio.

Obs. Meek was inclined to regard this species the same as A. lamellosa. It is, however, distinct. See A. missouriensis.

Athyris harpalyce Billings=Whitfieldella harpalyce.

Athyris hawni Swallow=Seminula hawni.

Athyris headi Billings=Catazyga headi.

Athyris headi anticostiensis Billings=Catazyga erratica.

Athyris headi borealis Billings=Catazyga erratica.

Athyris hirsuta Hall=Cleiothyris hirsuta.

Athyris incrassata Hall. Burlington (L. Carb.).

Athyris incrassata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 600, pl. 12, fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 90, pl. 46, fig. 21; pl. 83, fig. 39.

Athyris incrassatus Keyes, Geol. Survey Missouri, V, 1895, p. 91, pl. 41, fig. 10.

Loc. Burlington, Iowa; Quincy, Illinois; Hannibal, Missouri.

Digitized by Google

Athyris intermedia Nicholson=Whitfieldella intermedia.

Athyris intervarica McChesney. Burlington (L. Carb.).

Athyris intervarica McChesney, Descriptions New Pal. Foss., 1861, p. 78.

Loc. Burlington, Iowa.

Obs. May be the same as A. lamellosa L'Eveillé.

Athyris (?) jacksoni (Swallow). Upper Coal Measures.

Spirigera jacksoni Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 651.

Loc. Cass County, Missouri.

Athyris julia Billings=Whitfieldella julia.

Athyris junia Billings=Hyattella junia.

Athyris lamellosa (L'Eveillé). Waverly-Keokuk (L. Carb.).

Spirifer lamellosus L'Eveillé, Mém. Soc. Géol. de France, II, 1835, p. 39, figs. 21–23.

Athyris lamellosa Meek, Pal. Ohio, II, 1875, p. 283, pl. 14, fig. 6.—Herrick, Bull Denison Univ., III, 1888, p. 49, pl. 2, fig. 7.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 90, pl. 46, figs. 16–20.

Athyris ashlandensis Herrick, Bull. Denison Univ., IV, 1888, p. 24, pl. 3, fig. 6;—Geol. Ohio, VII, 1895, pl. 23, fig. 10.

Loc. Europe; Sciotoville, and Licking County, Ohio; Lebanon, Kentucky; Crawfordsville, Indiana; New Mexico.

Obs. See A. intervarica McChesney.

Athyris lara Billings=Atrypa lara.

Athyris maconensis Swallow=Seminula maconensis.

Athyris maia Billings=Martinia maia.

Athyris minima Swallow=A. fultonensis.

Athyris minutissima Webster. Chemung (Dev.).

Athyris minutissima Webster, American Nat., XXII, 1888, p. 1015.

Loc. Near Rockford, Iowa.

Athyris missouriensis Swallow=Cleiothyris missouriensis.

Athyris missouriensis (A. Winchell). Chouteau (L. Carb.).

Spirigera missouriensis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 117.

Loc. Louisiana, Missouri; Medina County, Ohio.

Obs. Should be compared with A. hannibalensis.

Athyris monticola (White). Lower Carboniferous.

Spirigera monticola White, Wheeler's Geogr. Geol. Expl. and Survey west 100 Merid., Prel. Rep., 1874, p. 16;—Final Rep. Ibidem, IV, 1875, p. 91, pl. 5, fig. 11.

Loc. Mountain Spring, Nevada.

Athyris naviformis Billings=Whitfieldella naviformis.

Athyris nitida Billings=Whitfieldella nitida.

Athyris obmaxima McChesney=Cleiothyris obmaxima.

Athyris obvia McChesney=Cleiothyris obvia.

Athyris ohioensis (A. Winchell). Waverly (L. Carb.).

Spirigera ohioensis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 118.

Athyris ohioensis Herrick, Bull. Denison Univ., III, 1888, p. 49, pl. 2, fig. 1.

Loc. Akron and Sciotoville, Ohio.

Athyris orbicularis McChesney=Cleiothyris orbicularis.

Digitized by Google

Athyris (?) ottervillensis Miller. Middle Devonian.

Athyris ottervillensis Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 314, pl. 9, figs. 14, 15.

Loc. Near Otterville, Missouri.

Athyris papilioniformis McChesney. Kaskaskia (L. Carb.).

Athyris spiriferoides McChesney (non Eaton, 1831), Descriptions New Pal. Foss., 1860, p. 46.

Athyris? papilioniformis McChesney, Ibidem, 1865, pl. 6, fig. 4;—Trans. Chicago Acad. Sci., I, 1868, p. 33, pl. 6, fig. 4.

Loc. Fountain Bluff, Illinois.

Athyris parvirostris Meek and Worthen=Cleiothyris roissyi.

Athyris parvula Whiteaves. Hamilton (Dev.).

Athyris parvula Whiteaves, Cont. Canadian Pal., I, 1891, p. 228, pl. 32, figs. 4, 5.

Loc. Athabasca River, Canada.

Athyris pectinifera? Swallow (non Sowerby)=Cleiothyris roissyi.

Athyris (?) perinflata McChesney. Keokuk (L. Carb.).

Athyris perinflata McChesney, Descriptions New Pal. Foss., 1861, p. 81.

Loc. Nauvoo, Illinois.

Athyris persinuata Meek=Seminula persinuata.

Athyris planosulcata American authors (non Phillips)=Cleiothyris roissyi.

Athyris plattensis Swallow=Seminula plattensis.

Athyris polita Hall. Chemung (Dev.).

Atrypa polita Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, Tables of Organic Remains, 65, fig. 5.

Athyris ? polita Hall, Pal. New York, IV, 1867, p. 293, pl. 47, figs. 21–33.

Athyris polita Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 46, figs. 1–5

Loc. Jasper, Randolph, and Albion, New York.

Athyris prinstana Billings=Hindella prinstana.

Athyris prouti (Swallow). Chouteau (L. Carb.).

Spirigera prouti Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 649.

Athyris prouti Keyes, Geol. Survey Missouri, V, 1895, p. 91.

Loc. St. Louis County, etc., Missouri.

Athyris reflexa Swallow=Cleiothyris reflexa.

Athyris roissyi=Cleiothyris roissyi.

Athyris singletoni Swallow=Seminula singletoni.

Athyris (?) solitaria Billings. Anticosti (Sil.).

Athyris solitaria Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 48.

Loc. Anticosti.

Athyris spiriferoides McChesney (non Eaton)=A. papilioniformis.

Athyris spiriferoides (Eaton). Corniferous and Hamilton (Dev.).

Terebratula spiriferoides Eaton, American Jour. Sci., XXI, 1831, p. 137;—Geological Text-book, 1832, p. 46.

Atrypa concentrica Conrad (non von Buch), Ann. Rep. Geol. Survey New York, 1838, p. 111.—Hall, Geol. New York; Rep. Fourth Dist, 1843, p. 198, fig. 5.

Spirifera spiriferoides Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 153, figs. 1, 2.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 828, fig. 667.

Athyris spiriferoides Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 93, figs. 1–4;—Fifteenth Rep. Ibidem, 1862, p. 180, figs. 1–4;—Pal. New York, IV, 1867, p. 285, pl. 46, figs. 5–31.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 89, figs. 60, 61; pl. 45, figs. 11–27.

Digitized by Google

Athyris spiriferoides (Eaton)—Continued.

Athyris concentrica Billings, Canadian Jour., VI, 1861, p. 145, figs. 54–57;—Geol. Canada, 1863, p. 373, fig. 399; p. 385, fig. 421.

Loc. New York; Pennsylvania; Maryland; Virginia; Cayuga and Widder, Canada.

Athyris squamosa Worthen=Cleiothyris squamosa.

Athyris sublamellosa Hall=Cleiothyris roissyi.

Athyris subquadrata Hall=Seminula subquadrata.

Athyris subtilita Hall=Seminula argentea.

Athyris trinucleus Hall=Seminula trinucleus.

Athyris trisinuatus McChesney=Meristina trisinuata.

Athyris tumida Roemer=Meristina tumida.

Athyris (?) tumidula Billings. Anticosti (Sil.).

Athyris tumidula Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 47.

Loc. Anticosti.

Obs. Probably a species of Whitfieldella.

Athyris (?) turgida Shaler. Anticosti (Sil.).

Athyris turgida Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 69.—Miller, N. American Geol. Pal., 1889, p. 335.

Loc. Anticosti.

Athyris ultravarica McChesney. Keokuk (L. Carb.).

Athyris ultravarica McChesney, Descriptions New Pal. Fossils, 1861, p. 79.

Loc. Keokuk, Iowa.

Athyris umbonata Billings=Hindella umbonata.

Athyris unisulcata Billings=Pentagonia unisulcata.

Athyris vittata Hall=A. fultonensis.

ATRYPA Dalman. Genotype Anomia reticularis Linnæus.

Atrypa Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, p. 102.—Billings, Canadian Nat. Geol., I, 1856, p. 134;—Canadian Jour., VI, 1861, p. 264.—Whitfield, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 141, pl. 1.—Hall, Pal. New York, IV, 1867, p. 312.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 88.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 163;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 818.

Atrypa æquiradiata Conrad=Rensselæria æquiradiata.

Atrypa acutiplicata Conrad=Anoplotheca acutiplicata.

Atrypa acutirostrum Hall=Rhynchonella acutirostris.

Atrypa affinis Vanuxem=A. reticularis.

Atrypa altilis Hall=Camarotœchia plena.

Atrypa ambigua Hall=Camarella ambigua.

Atrypa aprinis Hall=Homœospira apriniformis.

Atrypa arata Conrad=Pentamerella arata.

Atrypa aspera American authors=A. spinosa.

Atrypa aspera occidentalis Hall=A. hystrix occidentalis.

Atrypa bidens Hall=Rhynchonella bidens.

Atrypa bidentata Hall=Rhynchonella bidentata.

Atrypa bisulcata Hall (non Vanuxem)=Cyclospira bisulcata.

Atrypa bisulcata Vanuxem (non Hall)=Whitfieldella bisulcata.

Atrypa brevirostris Hall=Anastrophia brevirostris.

Digitized by Google

Atrypa calvini Nettelroth=A. rugosa.
Atrypa camura Hall=Trematospira camura.
Atrypa capax Conrad=Rhynchotrema capax.
Atrypa chemungensis Conrad=A. reticularis.
Atrypa circulus Hall=Parastrophia hemiplicata.
Atrypa comis Owen=Gypidula comis.
Atrypa concentrica Conrad, and Hall=Athyris spiriferoides.
Atrypa concinna Hall=Nucleospira concinna.
Atrypa congesta Conrad=Hyattella congesta.
Atrypa congregata Conrad=Camarotœchia congregata.
Atrypa contracta Hall=Camarotœchia contracta.
Atrypa corallifera Hall=Dictyonella corallifera.
Atrypa crassirostrum Hall=Whitfieldella cylindrica.
Atrypa cuboides Vanuxem, and Hall=Hypothyris cuboides.
Atrypa cuneata Hall=Rhynchotretra cuneata americana.
Atrypa cuspidata Hall=Triplecia cuspidata.
Atrypa cylindrica Hall=Whitfieldella cylindrica.
Atrypa deflecta Hall=Zygospira deflecta.
Atrypa dentata Hall=Rhynchotrema dentata.

Atrypa desquamata Sowerby. Middle Devonian.

Atrypa desquamata Sowerby, Trans. Geol. Soc., 2d ser., V, 1840, pl. 56, figs. 19, 20.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 150, pl. 14, fig. 4.
Loc. Europe; Petoskey, Michigan; Eureka district, Nevada.

Atrypa disparilis Hall=Atrypina disparilis.
Atrypa dubia Hall=Protorhyncha dubia.
Atrypa dumosa Hall=A. spinosa.
Atrypa duplicata Hall=Camarotœchia duplicata.

Atrypa ellipsoidea Nettelroth. Corniferous (Dev.).

Atrypa ellipsoidea Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 90.
Loc. Falls of Ohio.

Atrypa elongata Conrad=Rensselæria ovoides.
Atrypa emacerata Hall=Rhynchonella emacerata.
Atrypa equiradiata Hall=Camarotœchia equiradiata.
Atrypa exigua Hall=Zygospira exigua.
Atrypa eximia Hall=Camarotœchia eximia.
Atrypa extans Emmons=Triplecia extans.
Atrypa flabella Shaler=Anoplotheca hemispherica.
Atrypa flabellites Conrad=Anoplotheca flabellites.
Atrypa galeatus Dalman=Gypidula galeata.

Atrypa(?) gibbosa Hall. Clinton (Sil.).

Atrypa gibbosa Hall, Pal. New York, II, 1852, p. 79, pl. 20, fig. 10.
Loc. Clinton, New York.

Atrypa globuliformis Vanuxem=Leiorhynchus globuliforme.
Atrypa hemiplicata Hall=Parastrophia hemiplicata.
Atrypa hemispherica Sowerby=Anoplotheca hemispherica.
Atrypa hirsuta Hall=Parazyga hirsuta.

Digitized by Google

Atrypa hystrix Hall. Chemung (Dev.).

Atrypa hystrix Hall, Geology N. Y.; Rep. Fourth Dist., 1843, p. 271, fig. 2.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 829, fig. 681.—Hall, Pal. New York, IV, 1867, p. 326, pl. 53A, figs. 15–17.—Whitfield, Geol. Wisconsin, IV, 1882, p. 333, pl. 26, fig. 5.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 55, fig. 23.

Loc. Steuben County, New York; Pennsylvania; Rockford, Iowa; Milwaukee, Wisconsin.

Obs. See A. spinosa.

Atrypa hystrix elongata Webster. Chemung (Dev.).

Atrypa hystrix var. elongata Webster, American Nat., XXII, 1888, p. 1104.

Loc. Near Rockford, Iowa.

Atrypa hystrix occidentalis Hall. Middle Devonian.

Atrypa aspera var. occidentalis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 515, pl. 6, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 55, figs. 18–20.

Atrypa aspera Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 403, pl. 13, fig. 7.

Loc. Independence, Davenport, etc., Iowa; Rock Island, Illinois.

Obs. This variety is probably more closely related to A. hystrix than to A. aspera.

Atrypa hystrix planosulcata Webster. Chemung (Dev.).

Atrypa hystrix var. planosulcata Webster, American Nat., XXII, 1888, p. 1104.

Loc. Near Rockford, Iowa.

Atrypa imbricata Hall (non Sowerby)=A. nodostriata.

Atrypa impressa Hall=A. reticularis impressa.

Atrypa impressa Shaler (non Hall)=A. reticularis.

Atrypa increbescens Hall=Rhynchotrema inæquivalvis.

Atrypa intermedia Hall=Whitfieldella intermedia.

Atrypa interplicata Hall=Anastrophia interplicata.

Atrypa lævis Vanuxem=Meristella lævis.

Atrypa lacunosa Vanuxem=Anastrophia verneuili.

Atrypa lamellata Hall=Rhynchonella lamellata.

Atrypa(?) lara (Billings). Anticosti (Sil.).

Athyris lara Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 47.

Atrypa lara Davidson, Suppl. British Sil. Brach., Palæontographical Soc., 1882, p. 121.

Loc. Anticosti.

Obs. Said to have a true Atrypa loop and spires. The exterior is smooth. Probably the type of a new genus.

Atrypa laticorrugata Foerste. Clinton (Sil.).

Atrypa lati-corrugata Foerste, Geol. Ohio, VII, 1895, p. 591, pl. 57A, fig. 16.

Loc. Dayton, Ohio.

Atrypa laticostata Hall (non Phillips)=Camarotœchia contracta.

Atrypa lentiformis Vanuxem=A. reticularis.

Atrypa limitaris Hall=Leiorhynchus limitare.

Atrypa (?) lingulata Nicollet. Lower Carboniferous.

Atrypa lingulata Nicollet, Rep. Hydrog. Basin Up. Miss. River, 1843, p. 167.

"Subfusiform; valves nearly equally convex; inferior valve with a longitudinal sinus; base projecting in the middle, the margin of the projection truncated. St. Louis, and also the bluff beneath Rockwell, Illinois."

Digitized by Google

Atrypa marginalis (Dalman). Niagara (Sil.).

Terebratula marginalis Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, p. 59, pl. 6, fig. 6.

Atrypa marginalis Roemer, Sil. Fauna west. Tennessee, 1860, p. 69, pl. 5, fig. 10.—Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 46.—Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 197.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 314, pl. 6, figs. 8, 9;—Geol. Ohio, VII, 1895, p. 591, pl. 25, figs. 6, 9; pl. 31, figs. 8, 9.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 55, figs. 24, 25.

Trematospira matthewsoni McChesney, Descriptions New Pal. Foss., 1860, p. 71;—Trans. Chicago Acad. Sci., I, 1868, p. 32, pl. 7, fig. 3.

Atrypa nodostriata Foerste (non Hall), Bull. Denison Univ., I, 1885, p. 90, pl. 13, fig. 9.

Atrypa marginalis var. multistriata Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 316, pl. 6, fig. 8.

Loc. Europe; Anticosti; Dayton, Ohio; Hanover, Indiana; Louisville, Kentucky; Decatur County, Tennessee; Bridgeport, Illinois.

Atrypa masonii (Salter). Silurian.

Rhynchonella masonii Salter, Sutherland's Jour. Voyage Baffins Bay, etc., II, 1852, p. cexxi, pl. 5, fig. 5.—Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 596.

Loc. Near Wellington Channel, Bessels Bay, lat. 81° 6′.

Atrypa medialis Vanuxem=Eatonia medialis.

Atrypa mesacostalis Hall=Leiorhynchus mesacostale.

Atrypa missouriensis Miller. Middle Devonian.

Atrypa missouriensis Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 315, pl. 9, figs. 19–21.

Loc. Near Otterville, Missouri.

Atrypa modesta Hall=Zygospira modesta.

Atrypa nasuta Conrad=Meristella nasuta.

Atrypa naviformis Hall=Whitfieldella naviformis.

Atrypa neglecta Hall=Camarotœchia neglecta.

Atrypa nitida Hall=Whitfieldella nitida.

Atrypa nitida oblata Hall=Whitfieldella oblata.

Atrypa nodostriata Foerste (non Hall)=A. marginalis.

Atrypa nodostriata Hall. Clinton and Niagara (Sil.).

Atrypa imbricata Hall (non Sowerby), Geol. N. Y.; Rep. Fourth Dist., 1843, Tab. Organic Remains, 13, fig. 1.

Atrypa nodostriata Hall, Pal. New York, II, 1852, p. 272, pl. 56, fig. 2.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 133, pl. 7, figs. 12–14.

Loc. Lockport, New York; Yellow Springs, Ohio; Louisville, Kentucky; Wisconsin.

Atrypa nucleolata Hall=Whitfieldella nucleolata.

Atrypa nucleus Hall=Triplecia nucleus.

Atrypa nustella Castelnau=Eatonia peculiaris.

Atrypa oblata Hall=Whitfieldella oblata.

Atrypa obtusiplicata Hall=Camarotœchia obtusiplicata.

Atrypa octocostata Conrad=Pentamerella arata.

Atrypa palmata Morris and Sharpe=Anoplotheca flabellites.

Atrypa peculiaris Conrad=Eatonia peculiaris.

Digitized by Google

Atrypa phoca (Salter). Silurian.

Rhynchonella phoca Salter, Sutherland's Jour. Voyage Baffins Bay, etc., II, 1852, p. ccxxvi, pl. 5, figs. 1–3.

Atrypa phoca Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 576.

Loc. Cape Riley, Cornwallis, Seal Islands, Bessels Bay, lat. 81° 6′, and Dobbins Bay, lat. 79° 41′, Arctic America.

Atrypa planoconvexa Hall=Anoplotheca planoconvexa.

Atrypa pleiopleura Conrad=Camarotœchia pleiopleura.

Atrypa plena Hall=Camarotœchia plena.

Atrypa plicata Hall=Rhynchonella plicata.

Atrypa plicatella Hall=Rhynchonella plicatella.

Atrypa plicatula Hall=Anoplotheca plicatula.

Atrypa plicifera Hall=Camarotœchia plena.

Atrypa polita Hall=Athyris polita.

Atrypa prisca Vanuxem=A. reticularis.

Atrypa pseudomarginalis Hall. Up. Helderberg (Dev.).

Atrypa pseudomarginalis Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 84;—Fifteenth Rep. Ibidem, 1862, p. 189;—Pal. New York, IV, 1867, p. 327, pl. 53, figs. 1, 2.—Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 55, figs. 26, 27.

Loc. Schoharie, New York.

Atrypa quadricostata Hall, 1843=Leiorhynchus quadricostatum.

Atrypa quadricostata Hall, 1852=Hyattella congesta.

Atrypa rectiplicata Conrad=Spirifer rectiplicatus.

Atrypa recurvirostris Hall=Zygospira recurvirostris.

Atrypa reticularis (Linnæus). Silurian and Devonian.

Anomia reticularis Linné, Systema Naturæ, ed. xii, I, 1767, p. 1132.

Atrypa chemungensis Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 265.—Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 182, fig. 4.

Hipparionyx consimilaris Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 132, fig. 2.

Atrypa affinis Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 88, fig. 12.—Hall, Ibidem, Rep. Fourth Dist, 1843, p. 88, fig. 12.

Atrypa prisca Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 139, fig. 5.—Hall, Ibidem, Rep. Fourth Dist., 1843, p. 175, fig. 5; p. 198, fig. 4.—Owen, Geol. Expl. Iowa, Wisconsin, Illinois, 1844, pl. 12, figs. 2, 10.—Billings, Canadian Nat. Geol., I, 1856, p. 474, pl. 7, fig. 11.

Atrypa lentiformis Vanuxem, Geol. New York; Rep Third Dist., 1842, p. 163, fig. 3; p. 164.—Hall, Ibidem, Rep. Fourth Dist., 1843, p. 215, fig. 3.

Strophomena ithacensis Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 174, fig. 2. (On the authority of Professor Williams.)

Atrypa tribulis Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 271, fig. 3.

Terebratula prisca Castelnau, Essai Syst., Sil. l'Amérique Septentrionale, 1843, p. 40, pl. 13, fig. 8.

Terebratula reticularis Hall, American Jour. Sci., 2d ser., XX, 1849, p. 227.—Yandell and Shumard, Cont. Geol. Kentucky, 1847, p. 10.

Atrypa reticularis Hall, Pal. New York, II, 1852, p. 72, pl. 23, fig. 8; p. 270, pl. 55, fig. 5.—Billings, Canadian Nat. Geol., I, 1856, p. 137, pl. 2, fig. 10.—Hall, Geol. Survey Iowa, II, 1858, p. 515;—Pal. New York, III, 1859, p. 253, pl. 42, fig. 1.—Roemer, Sil. Fauna west. Tennessee, 1860, p. 69, pl. 5, fig. 9.—Billings, Canadian Jour., VI, 1861, p. 264, figs. 84–87;—Geol. Canada, 1863, p. 318,

Digitized by Google

Atrypa reticularis (Linnæus)—Continued.

fig. 335; p. 384, fig. 416.—Hall, Pal. New York, IV, 1867, p. 316, pl. 52, figs. 1–3, 7–12; pl. 53, figs. 3–19; pl. 53A, figs. 22, 23.—Meek, Trans. Chicago Acad. Sci., I, 1868, p. 97, pl. 13, fig. 13.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 432, pl. 13, fig. 11.—Meek, Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p. 347, pl. 1, fig. 6;—King's U. S. Geol. Survey Expl. 40th Parl., IV, 1877, p. 38, pl. 1, fig. 7; pl. 3, fig. 6.—Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 596.—Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 162, pl. 25, figs. 44–47.—White, Sec. Ann. Rep. Indiana Bureau Statistics and Geol., 1880, p. 502, pl. 5, figs. 7–9;—Tenth Rep. State Geol. Indiana, 1881, p. 134, pl. 5, figs. 7–9;—Ibidem, Eleventh Rep., 1882, p. 304, pl. 25, figs. 44–47.—Whitfield, Geol. Wisconsin, IV, 1882, p. 333, pl. 26, fig. 6.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 150, pl. 14, fig. 6.—Beecher and Clarke, Mem. New York State Mus. Nat. Hist., I, 1889, p. 51, pl. 4, figs. 12–20.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Survey, 1889, p. 91, pl. 14, figs. 12–23; pl. 15, fig. 1.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 314.—Whiteaves, Cont. Canadian Pal., I, 1892, p. 289, pl. 37, fig. 8.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 165, fig. 153; pl. 55, figs. 1–17.—Herrick, Geol. Ohio, VII, 1895, pl. 20, fig. 7.

Atrypa impressa Shaler (non Hall), Bull. Mus. Comp. Zool., 4, 1865, p. 68.

Loc. A characteristic fossil of the Silurian and Devonian throughout the world.

Atrypa reticularis impressa Hall. Schoharie grit (Dev.).

Atrypa impressa Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 122, figs. 1–7;—Pal. New York, IV, 1867, p. 315, pl. 51, figs. 1–9.

Loc. Schoharie, Clarksville, etc., New York.

Atrypa reticularis niagarensis Nettelroth. Niagara (Sil.).

Atrypa reticularis var. niagarensis Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 92, pl. 32, figs. 5–8, 44–47.

Loc. Jefferson County, Kentucky; Clarke County, Indiana.

Atrypa reticularis nuntia Hall and Whitfield. Hamilton (Dev.).

Atrypa reticularis Hall, Pal. New York, IV, 1867, p. 316, pl. 51, figs. 10–24.

Atrypa reticularis var. nuntia Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 199.

Loc. Falls of Ohio.

Atrypa reticularis ventricosa Hall and Whitfield. Hamilton (Dev.).

Atrypa reticularis Hall, Pal. New York, IV, 1867, p. 316, pl. 52, figs. 4–6.

Atrypa reticularis var. ventricosa Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 199.

Loc. Falls of Ohio.

Atrypa robusta Hall=Rhynchonella robusta.

Atrypa rostrata Hall=Meristella rostrata.

Atrypa rugosa Hall. Niagara (Sil.).

Atrypa rugosa Hall, Pal. New York, II, 1852, p. 271, pl. 56, fig. 1.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 171.

Rhynchonella rugosa Billings, Geol. Canada, 1863, p. 315, fig. 321.

Atrypa calvini Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 89, pl. 32, figs. 64–66.

Loc. Lockport, New York; Anticosti; Osgood, Indiana; Louisville, Kentucky.

Atrypa scitula Hall=Charionella scitula.

Atrypa semiplicata Conrad=Rhynchonella semiplicata.

Atrypa singularis Vanuxem=Eatonia singularis.

Digitized by Google

Atrypa sordida Hall=Rhynchonella sordida.

Atrypa spinosa Hall. Corniferous-Chemung (Dev.).

Atrypa spinosa Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 200, figs. 1, 2.—Whitfield, Geol. Wisconsin, IV, 1882, p. 333, pl. 26, figs. 7, 8.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 55, figs. 21, 22.

Atrypa dumosa Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 271, fig. 1.

Atrypa aspera Hall (non Schlotheim), Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 168.—Rogers, Geol. Pennsylvania, II, 1858, Pt. II, p. 828, fig. 671.—Meek, Trans. Chicago Acad. Sci., I, 1868, p. 96, pl. 13, fig. 12.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 88, pl. 14, figs. 1–11.

Atrypa aspera vel aspera Hall, Pal. New York, IV, 1867, p. 322, pl. 53A, figs. 1–14, 18, 24, 25.

Atrypa aspera? Meek, Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p. 348, pl. 1, fig. 2.

Atrypa reticularis var. aspera Whiteaves, Cont. Canadian Pal., I, 1891, pp. 229, 289.

Loc. New York; Pennsylvania; Maryland; Virginia; Kentucky; Ohio; Illinois; Iowa; Wisconsin; Ontario; Lockhart and Athabasca rivers, etc., Northwest Territory, Canada.

Obs. The Corniferous limestone specimens of A. spinosa are not always easily distinguished from A. reticularis. The fewer plications of the former, however, will usually distinguish it from the latter species. This tendency to fewer plications is more marked in the Hamilton formation and attains its climax in the Chemung, where the species is known as A. hystrix.

Atrypa subtrigonalis Hall=Rhynchonella subtrigonalis.

Atrypa sulcata Vanuxem=Whitfieldella sulcata.

Atrypa tenuilineata Hall=Dalmanella tenuilineata.

Atrypa tribulis Hall=A. reticularis.

Atrypa unguiformis Hall=Hipparionyx proximus.

Atrypa unisulcata Conrad=Pentagonia unisulcata.

ATRYPINA Hall and Clarke. Genotype Leptocœlia imbricata Hall.

Atrypina Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 161, fig. 152;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 815.

Atrypina clintoni Hall and Clarke. Clinton (Sil.).

Atrypina clintoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 162, pl. 53, figs. 7, 17–19; pl. 83, fig. 6.

Loc. Orleans County, New York.

Atrypina disparilis (Hall). Niagara (Sil.).

Atrypa disparilis Hall, Pal. New York, II, 1852, p. 277, pl. 57, fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 53, figs. 1–4.

Leptocœlia disparilis Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 77.

Trematospira? disparilis Hall, Sixteenth Rep., Ibidem, 1863, p. 60;—Trans. Albany Institute, IV, 1863, p. 146.

Cœlospira disparilis Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 162, pl. 25, figs. 39–43;—Eleventh Rep. State Geol. Indiana, 1882, p. 363, pl. 25, figs. 39–43.—Beecher and Clarke, Mem. New York State Mus. Nat. Hist., I, 1889, p. 64, pl. 5, figs. 17–23.

Loc. Wolcott, New York; Waldron, Indiana.

Obs. Davidson in 1882 regarded this species the same as Atrypa barrandei of Europe.

Digitized by Google

Atrypina imbricata Hall. Lower Helderberg (Dev.).

Leptocœlia imbricata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 106;—Pal. New York, III, 1859, p. 246, pl. 38, figs. 8–13.—Billings, Geol. Canada, 1863, p. 957, fig. 452.

Trematospira imbricata Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 60;—Trans. Albany Institute, IV, 1863, p. 146.—Keyes, Geol. Survey Missouri, V, 1895, p. 96.

Trematospira ? imbricata Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 381, pl. 7, fig. 2.

Atrypina imbricata Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 53, figs. 5, 6, 8–10.

Loc. Albany and Schoharie counties, New York; Perry County, Missouri.

Atrypina intermedia (Hall). Arisaig (Sil.).

Leptocœlia intermedia Hall, Canadian Nat. Geol., V, 1860, p. 147, fig. 5.—Dawson, Acadian Geology, 3d ed., 1878, p. 598, fig. 202.

Loc. Arisaig, Nova Scotia.

Avicula desquamata Hall=Obolella crassa.

AULACORHYNCHUS Dittmar. Genotype A. pachti Dittmar.

Aulacorhynchus Dittmar, Verhand. Kais. Mineral. Gessel. St. Petersburg, 2d ser., VII, 1871, p. 1, pl. 1, figs. 1–13.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 311;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 904.

Isogramma Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 568.

Aulacorhynchus millipunctatum (Meek and Worthen). Up. Coal Meas.

Chonetes ? ? millipunctata Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1870, p. 35;—Geol. Survey Illinois, V, 1873, p. 566, pl. 25, fig. 3.

Isogramma millipunctata Meek and Worthen, Ibidem, 1873, p. 568.

Aulacorhynchus millipunctatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 312, pl. 83, figs. 14, 15.

Chonetes millipunctatus Keyes, Geol. Survey Missouri, V, p. 54.

Loc. Marion County, Illinois; Kansas City, Missouri.

Aulosteges guadalupensis Shumard=Strophalosia guadalupensis.

Aulosteges spondyliformis White and St. John=Strophalosia spondyliformis.

Barrandella Hall and Clarke=Clorinda.

BARROISELLA Hall and Clarke. Genotype Lingula subspatulata Meek and Worthen (non Hall and Meek).

Barroisella Hall and Clarke, Pal. New York, Extract, VIII, Pt. I, 1890, p. 62;—Pal. New York, VIII, Pt. I, 1892, pp. 62, 64;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 230.

Barroisella subspatulata (Meek and Worthen). Black Slate (Dev.).

Lingula subspatulata Meek and Worthen (non Hall and Meek), Geol. Survey Illinois, III, 1868, p. 437, pl. 13, fig. 1.

Lingula subspatulata ? A. Winchell, Proc. American Phil. Soc., XII, 1870, p. 248.

Barroisella subspatulata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 63, pl. 2, figs. 14–16 and p. 164.

Loc. Jonesboro, Illinois; Louisville and Lebanon, Kentucky; Rockford, Indiana.

BEACHIA Hall and Clarke. Genotype Meganteris suessana Hall.

Beachia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 260;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 850.

Digitized by Google

Beachia suessana Hall. Oriskany (Dev.).

Meganteris suessana Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 100.

Rensselæria suessana Hall, Pal. New York, III, 1859, p. 459, pl. 107, figs. 1-15.

Beachia suessana Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 260, pl. 77, figs. 1-11.

Loc. Cumberland, Maryland; near Rondout, New York.

BEECHERIA Hall and Clarke. Genotype B. davidsoni Hall and Clarke.

Beecheria Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 300;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 866.

Beecheria davidsoni Hall and Clarke. Upper Carboniferous.

Beecheria davidsoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 300, fig. 224, pl. 79, figs. 33-36.

Loc. Windsor, Nova Scotia.

BILLINGSELLA Hall and Clarke.

Genotype Orthis pepina Hall=O. coloradoensis Shumard.

Billingsella and Protorthis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 230, 231;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 273.

Obs. Protorthis was founded on Orthis billingsi Hartt, a species rarely found in good preservation. The diagnostic character was supposed to be the presence of a rudimentary spondylium and the absence of a deltidium. In the National Museum collection, however, there are two artificial casts of the ventral valve made from Hartt's original specimens and other material collected by Mr. Walcott, showing O. billingsi to be without a spondylium. The rostral plate is the deltidium distorted by pressure to which these shells have been subjected. The only character of generic importance is that the geologically older species of Billingsella have a more rudimentary or nearly obsolete cardinal process than the type species. This difference, however, hardly justifies the retention of Protorthis.

Billingsella alberta (Walcott). Middle Cambrian.

Orthisina alberta Walcott, Proc. U. S. National Mus., XI, 1888, p. 442.

Loc. Mount Stephan, British Columbia.

Billingsella billingsi (Hartt). Middle Cambrian.

Orthis billingsi Hartt, Dawson's Acadian Geology, 2d ed., 1868, p. 644, fig. 223.—Walcott, Bull. U. S. Geol. Survey, 10, 1884, p. 17, pl. 1, fig. 1.—Matthew, Trans. Royal Soc. Canada, III, 1886, p. 43.

Orthis? billingsi Matthew, Ibidem, VIII, 1891, p. 131.

Protorthis billingsi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 219, 232, pl. 7A, figs. 14-20.

Loc. St. John, New Brunswick.

Billingsella coloradoensis (Shumard). Upper Cambrian.

Orthis coloradoensis Shumard, Trans. St. Louis Acad. Sci., I, 1860, p. 627.

Orthis pepina Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 134, pl. 6, figs. 23-27;—Trans. Albany Institute, V, 1867, p. 113.—Whitfield, Geol. Wisconsin, IV, 1882, p. 170, pl. 1, figs. 4, 5.

Orthis? (Orthisina?) pepina Hall, Second Ann. Rep. New York State Geologist, 1883, pl. 37, figs. 16-19.

Billingsella pepina Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 230, pl. 7, figs. 16-19; pl. 7A, figs. 7-9.

Orthis (Billingsella) pepina Sardeson, Bull. Minnesota Acad. Nat. Sci., IV, 1896, p. 96.

Loc. Burnett County, Texas; Lake Pepin, Minnesota; St. Croix River and Berlin, Wisconsin.

Digitized by Google

Billingsella festinata (Billings). Lower Cambrian.

Orthisina festinata Billings, Pal. Fossils, I, 1861, p. 10, figs. 11, 12;—Geol. Vermont, II, 1861, p. 949, figs. 350–352;—American Jour. Sci., 2d ser., XXXIII, 1862, p. 105;—Geology Canada, 1863, p. 284, fig. 289.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 120, pl. 7, fig. 7;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 613, pl. 72, fig. 7.

Billingsella festinata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 230.

Loc. Swanton, Vermont; York, Pennsylvania.

Billingsella (?) grandæva (Billings). Calciferous (Ord.).

Orthisina grandæva Billings, Canadian Nat. Geol., IV, 1859, p. 349, fig. 1;—Geology Canada, 1863, p. 113, fig. 21.

Billingsella? grandæva Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 231.

Loc. Mingan Island, Gulf of St. Lawrence.

Billingsella latourensis (Matthew). Middle Cambrian.

Kutorgina latourensis Matthew, Trans. Royal Soc. Canada, III, 1886, p. 42, pl. 5, fig. 18.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 93, 95, 233, pl. 4, figs. 18–20.

Loc. Portland, New Brunswick.

Billingsella (?) laurentina (Billings). Anticosti (Sil.).

Orthis laurentina Billings, Geol. Survey Canada; Rep. for 1856, 1857, p. 297;—Pal. Fossils, I, 1862, p. 138, fig. 115.

Billingsella? laurentina Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 194, 231, 238, pl. 7A, figs. 1–6.

Loc. Anticosti.

Billingsella orientalis (Whitfield). Lower Cambrian.

Orthisina orientalis Whitfield, Bull. American Mus. Nat. Hist., I, 1884, p. 144, pl. 14, fig. 6.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 120, pl. 7, fig. 6;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 613, pl. 72, fig. 8.

Billingsella orientalis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 230.

Loc. Georgia and Swanton, Vermont.

Billingsella (?) primordialis (Whitfield). Calciferous (Ord.).

Streptorhynchus? primordiale Whitfield, Bull. American Mus. Nat. Hist., I, 1886, p. 301, pl. 24, fig. 7.

Billingsella? primordiale Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 231.

Loc. Fort Cassin, Vermont.

Billingsella quacoensis (Matthew). Middle Cambrian.

Orthis quacoensis Matthew, Trans. Royal Soc. Canada, III, 1886, p. 43, pl. 5, fig. 20.

Orthis? quacoensis Matthew, Ibidem, VIII, 1891, p. 131.

Protorthis quacoensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 232, pl. 7A, fig. 21.

Loc. Portland and St. Martins, New Brunswick.

Billingsella transversa (Walcott). Lower Cambrian.

Orthisina? transversa Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 121, pl. 7, fig. 5;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 613, pl. 72, fig. 9.

Billingsella transversa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 230.

Loc. Georgia, Vermont.

Billingsella whitfieldi (Walcott). Lower Cambrian.

Kutorgina whitfieldi Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 18, pl. 9, fig. 4.

Loc. Eureka district, Nevada.

Billingsia Ford (non de Koninck, 1876)=Elkania.

Digitized by Google

BILOBITES Linnæus. Genotype Anomia biloba Linnæus.

Bilobites Linnæus, Systema Naturæ, ed. Muller, VI, 1775, p. 325.—Hall, Bull. Geol. Soc. America, I, 1889, p. 21.—Beecher, American Jour. Sci., 3d ser., XLII, 1891, p. 51.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 204, 223;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 269.

Dicœlosia King, Mon. Permian Fossils England, Pal. Soc., 1850, p. 106.

Bilobites acutilobus (Ringueberg). Niagara (Sil.).

Orthis acutiloba Ringueberg, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 134, pl. 7, fig. 5.

Bilobites acutilobus Beecher, American Jour. Sci., 3d ser., XLII, 1891, p. 52, pl. 1, fig. 1.

Loc. Lockport, New York.

Bilobites bilobus (Linnæus). Niagara (Sil.).

Anomia biloba Linnæus, Systema Naturæ, ed. XII, 1767, p. 1154.

Delthyris sinuatus Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 105, fig. 8.

Spirifer bilobus Hall, American Jour. Sci., 2d ser., XX, 1849, p. 228;—Pal. New York, IV, 1852, p. 260, pl. 54, fig. 1.

Orthis biloba Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 85;—Eleventh Rep. State Geol. Indiana, 1882, p. 286, pl. 27, fig. 16.

Bilobites bilobus Beecher, American Jour. Sci., 3d ser., XLII, 1891, p. 52, pl. 1, fig. 28.

Bilobites biloba Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 190, 204, 205, 223, pl. 5B, figs. 11–14.

Loc. Lockport, New York; Waldron, Indiana; Wisconsin.

Bilobites varicus (Conrad). Lower Helderberg (Dev.).

Delthyris bilobata Conrad (not Orthis bilobata Sowerby), Second Ann. Rep. New York Geol. Survey, 1838, pp. 112, 118.

Delthyris varica Conrad, Jour Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 262, pl. 14, fig. 20.

Orthis varica Hall, Pal. New York, III, 1859, p. 179, pl. 24, fig. 1.

Orthis (Dicœlosia) varica Hall, Second Ann. Rep. New York State Geol., 1883, pl. 35, figs. 38–42.

Bilobites varicus Beecher, American Jour. Sci., 3d ser., XLII, 1891, p. 52, pl. 1, figs. 3–27.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 204, 223, pl. 5B, figs. 15–19.

Loc. Albany and Schoharie counties, New York; Decatur County, Tennessee; St. Blandine, New Brunswick.

BOTSFORDIA Matthew. Genotype Obolus pulcher Matthew.

Obolus (Botsfordia) Matthew, Trans. Royal Soc. Canada, VIII, 1891, p. 148; X, p. 90.

Botsfordia pulchra Matthew. Middle Cambrian.

Obolus pulcher Matthew, Canadian Record of Science, III, 1889, p. 306;—Trans. Royal Soc. Canada, VII, 1890, p. 151, pl. 8, figs. 1, 2.

Obolus (Botsfordia) pulcher Matthew, Trans. Royal Soc. of Canada, VIII, 1891, p. 148.

Obolus? pulcher Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 81, 183, pl. 4K, fig. 22.

Obolus (Botsfordia) pulchra Matthew, Trans. Royal Soc. Canada, X, 1894, p. 90, pl. 16, fig. 3.

Botsfordia pulchra Matthew, Trans. New York Acad. Sci., XIV, 1895, p. 115, pl. 3.

Loc. Canton Island, New Brunswick.

Brachymerus Shaler (non Dejean, 1834)=Anastrophia.

Brachymerus reversus Shaler=Parastrophia reversa.

Digitized by Google

Brachyprion Shaler=Stropheodonta.
Brachyprion geniculatum Shaler=Stropheodonta geniculata.
Brachyprion leda Shaler=Rafinesquina leda.
Brachyprion ventricosum Shaler=Stropheodonta ventricosa.

CAMARELLA Billings. Genotype C. volborthi Billings.

Camarella Billings, Canadian Nat. Geol., IV, 1859, p. 301;—Ibidem, VI, 1861, p. 316.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 122.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 48.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 219;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 838.

Camarella ambigua (Hall). Trenton (Ord.).

Atrypa ambigua Hall, Pal. New York, I, 1847, p. 143, pl. 33, figs. 8, 9.
Triplesia? ambigua Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 65.
Camarella ambigua Miller, American Pal. Foss., 1879, p. 107.
Loc. Middleville, New York.

Camarella antiquata Billings=Protorhyncha antiquata.
Camarella bisulcata Emmons=Cyclospira bisulcata.
Camarella bernensis Sardeson=Parastrophia hemiplicata.

Camarella breviplicata Billings. Calciferous (Ord.).

Camarella breviplicata Billings, Pal. Fossils, I, 1865, p. 304, fig. 295.
Loc. Stanbridge, Quebec, Canada.

Camarella calcifera Billings=Syntrophia calcifera.
Camarella circularis Miller=Parastrophia hemiplicata.

Camarella(?) costata Billings. Calciferous (Ord.).

Camarella? costata Billings, Pal. Fossils, I, 1865, p. 305, fig. 296.
Loc. Stanbridge, Quebec, Canada.

Camarella hemiplicata Billings=Parastrophia hemiplicata.

Camarella lenticularis Billings. Anticosti (Sil.).

Camarella lenticularis Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 45.
Loc. Anticosti.

Camarella longirostris Billings. Chazy (Ord.).

Camarella longirostra Billings, Canadian Nat. Geol., IV, 1859, p. 302; p. 445, fig. 23;—Geol. Canada, 1863, p. 127, fig. 53.
Loc. Mingen Islands, Gulf of St. Lawrence.

Camarella minor Walcott=Protorhyncha minor.
Camarella ops Billings=Parastrophia ops.
Camarella owatonnensis Sardeson=Cyclospira bisulcata.

Camarella panderi Billings. Black River (Ord.).

Camarella panderi Billings, Canadian Nat. Geol., IV, 1859, p. 302;—Geol. Canada, 1863, p. 143, fig. 78.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 220, pl. 62, figs. 19–23.
Loc. Pauquettes Rapids, Canada; Curdsville, Kentucky.

Camarella parva Billings. Calciferous (Ord.).

Camarella parva Billings, Pal. Fossils, I, 1865, p. 219.
Camarella parva? Matthew, Trans. Royal Soc. Canada, XI, 1893, p. 103, pl. 7, fig. 9.
Loc. Table Head and Portland Creek, Newfoundland; near St. John, New Brunswick.

Digitized by Google

Camarella polita Billings. Calciferous (Ord.).

Camarella polita Billings, Pal. Fossils, I, 1865, p. 305, fig. 297 on p. 304.

Loc. Stanbridge, Quebec, Canada.

Camarella reversa Billings=Anastrophia reversa.

Camarella varians Billings. Calciferous-Chazy (Ord.).

Camarella varians Billings, Canadian Nat. Geol., IV, 1859, p. 445, fig. 24;—Geol. Canada, 1863, p. 127, fig. 52;—Pal. Fossils, I, 1865, p. 220.

Loc. Mingan Islands, Gulf of St. Lawrence; Table Head and Portland Creek, Newfoundland; Chazy, New York.

Camarella volborthi Billings. Black River (Ord.).

Camarella volborthi Billings, Canadian Nat. Geol., IV, 1859, p. 301;—Geol. Canada, 1863, p. 143, fig. 77.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 220, pl. 62, figs. 11–18; pl. 84, fig. 42.

Loc. Pauquettes Rapids, Ontario, Canada.

Camarium Hall=Merista.

Camarium elongatum Hall=Merista typus.

Camarium meeki Hall=Meristella meeki.

Camarium princeps Hall=Meristella princeps.

Camarium typus Hall=Merista typus.

CAMAROPHORELLA Hall and Clarke.

Genotype Pentamerus lenticularis White and Whitfield.

Camarophorella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 215;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 838.

Camarophorella lenticularis (White and Whitfield).

Burlington (L. Carb.).

Pentamerus lenticularis White and Whitfield, Jour. Boston Soc. Nat. Hist., VIII, 1862, p. 295.

Camarophorella lenticularis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 215, pl. 62, figs. 46–48.

Loc. Burlington, Iowa.

CAMAROPHORIA King. Genotype Terebratula schlotheimi von Buch.

Camarophoria King, Ann. Mag. Nat. Hist., XVIII, 1846, p. 89;—Mon. Permian Foss. England, Pal. Soc., 1850, p. 113.—Hall, Pal. New York, IV, 1867, p. 435.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 212;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 837.

Stenochisma Œhlert (non Conrad), Fischer's Manuel Conchyliologie, 1887, p. 1309.

Camarophoria(?) bisulcata Shumard. Upper Carboniferous.

Camarophoria(?) bisulcata Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 296, pl. 11, fig. 2.

Loc. Guadalupe Mountains of New Mexico and Texas.

Camarophoria caput-testudinis (White). Burlington (L. Carb.).

Rhynchonella caput-testudinis White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 23.

Camarophoria caput-testudinis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 215.

Loc. Burlington, Iowa.

Obs. Probably identical with C. ringens Swallow.

Camarophoria eucharis Hall=Camarospira eucharis.

Camarophoria explanata (McChesney). Kaskaskia (L. Carb.).

Rhynchonella explanata McChesney, Descriptions New Pal. Foss., 1860, p. 50;—Trans. Chicago Acad. Sci., I, 1868, p. 30, pl. 6, fig. 7.

Digitized by Google

Camarophoria explanata (McChesney)—Continued.

Pugnax explanatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 60, figs. 43–45.

Loc. Chester, Illinois; Princeton, Kentucky.

Obs. Specimens of this species in Mr. Ulrich's collection prove it to be a Camarophoria.

Camarophoria giffordi Worthen=Enteletes hemiplicatus.

Camarophoria globulina Geinitz (non Phillips)=Pugnax utah.

Camarophoria globulina Davidson=Pugnax globulina.

Camarophoria occidentalis Miller. Burlington (L. Carb.).

Camarophoria occidentalis Miller, Jour. Cincinnati Soc. Nat. Hist., IV, 1881, p. 8, pl. 7, fig. 7.

Loc. Lake Valley district, New Mexico.

Camarophoria osagensis Swallow=Pugnax utah.

Camarophoria ringens (Swallow). Keokuk (L. Carb.).

Rynchonella ringens Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 653.—Keyes, Geol. Survey Missouri, V, 1895, p. 102.

Camarophoria ringens Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 214.

Loc. Callaway County, Missouri.

Obs. Compare with C. caput-testudinis and Rhynchonella striata. The writer has seen specimens of R. ringens from Callaway County, Missouri, Swallow's original locality.

Camarophoria rhomboidalis Hall and Clarke. Corniferous (Dev.).

Camarophoria rhomboidalis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 366, pl. 62, figs. 25–29.

Loc. Cass County, Indiana.

Camarophoria subcuneata Hall. St. Louis (L. Carb.).

Rhynchonella subcuneata Hall, Trans. Albany Institute, IV, 1858, p. 11;—Geol. Survey Iowa, I, Pt. II, 1858, p. 658, pl. 23, fig. 3.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 51, pl. 6, figs. 47–49.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 333, pl. 29, figs. 47–49.—Herrick, Bull. Denison Univ., III, 1888, p. 39, pl. 7, fig. 23.—Keyes, Geol. Survey Missouri, V, 1895, p. 102.

Camarophoria subcuneata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pl. 62, figs. 34–37.

Loc. Spergen Hill and Bloomington, Indiana. In the Waverly at Granville, Ohio, according to Herrick.

Obs. See Rhynchonella arctirostrata.

Camarophoria subtrigona Meek and Worthen. Keokuk (L. Carb.).

Rhynchonella subtrigona Meek and Worthen, Proc. Acad. Nat. Sci., Philadelphia, 1860, p. 451.—Keyes, Geol. Survey Missouri, V, 1895, p. 102.

Rhynchonella parvini McChesney, Descriptions New Pal. Foss., 1861, p. 83;—Ibidem, 1865, pl. 6, fig. 2.

Camarophoria subtrigona Meek and Worthen, Geol. Survey Illinois, II, 1866, p. 251, pl. 18, fig. 7.—McChesney, Trans. Chicago Acad. Sci., I, 1868, p. 31, pl. 6, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 214, pl. 62, figs. 38–43.

Camarophoria ringens Hall and Clarke (non Swallow), Ibidem, 1893, pl. 84, fig. 5.

Loc. Keokuk, Iowa; Nauvoo and Warsaw, Illinois.

Camarophoria swallovana Shumard=Pugnax swallovana.

Camarophoria thera (Walcott). Lower Carboniferous.

Rhynchonella thera Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 223, pl. 7, fig. 6.

Loc. Eureka district, Nevada.

Digitized by Google

Camarophoria(?) wortheni (Hall). Warsaw (L. Carb.).

Rhynchonella wortheni Hall, Trans. Albany Institute, IV, 1858, p. 11.

Camarophoria? wortheni Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 54, pl. 6, figs. 35–39.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 334, pl. 29, figs. 35–39.

Camarophoria wortheni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 214.

Loc. Alton, Illinois.

CAMAROSPIRA Hall and Clarke.

Genotype Camarophoria eucharis Hall.

Camarospira Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 82;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 776.

Camarospira eucharis Hall. Corniferous (Dev.).

Camarophoria eucharis Hall, Pal. New York, IV, 1867, p. 368, pl. 57, figs. 40–45.

Camarospira eucharis Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 82, pl. 50, figs. 46–52.

Loc. Ontario, Canada; Cass County, Indiana.

CAMAROTŒCHIA Hall and Clarke.

Genotype Atrypa congregata Conrad.

Camarotœchia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 189;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 826.

Camarotœchia(?) acinus Hall. Niagara (Sil.).

Rhynchonella acinus Hall, Trans. Albany Institute, IV, 1863, p. 215;—Twenty-eighth Rep. New York State Mus. Nat. Hist, 1879, p. 163, pl. 26, figs. 7–11;—Eleventh Rep. State Geol. Indiana, 1882, p. 306, pl. 26, figs. 7–11.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 73, pl. 26, figs. 6, 13, 14, and pl. 32, figs. 13–16.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 35, pl. 4, figs. 9–11.

Camarotœchia? acinus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190.

Loc. Waldron, Indiana; Louisville, Kentucky.

Camarotœchia(?) acinus convexa (Foerste). Clinton (Sil.).

Rhynchonella acinus var. convexa Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 318, pl. 6, fig. 13;—Geol. Ohio, VII, 1895, p. 593, pl. 31, fig. 13.

Loc. Hanover, Indiana.

Camarotœchia æquiradiata Hall. Clinton (Sil.).

Atrypa equiradiata Hall, Pal. New York, II, 1852, p. 70, pl. 23, fig. 5.

Rhynchospira? equiradiata Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 77.

Rhynchonella æquiradiata Miller, N. American Geol. Pal., 1889, p. 367.

Camarotœchia æquiradiata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190.

Protorhyncha æquiradiata Hall and Clarke, Ibidem, 1895, pl. 56, figs. 7–9.

Loc. Oneida County, New York; Arisaig, Nova Scotia.

Camarotœchia (Plethorhyncha) barrandei Hall. Oriskany (Dev.).

Rhynchonella barrandi Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 82, figs. 1–3; p. 84, fig. 4;—Pal. New York, III, 1859, p. 442, pl. 103, figs. 3–8.

Plethorhyncha barrandi Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 191.

Loc. Albany and Schoharie counties, New York.

Camarotœchia billingsi Hall. Corniferous (Dev.).

Rhynchonella thalia Billings (non d'Orbigny, 1847), Canadian Jour., V, 1860, p. 272, figs. 23–25;—Geol. Canada, 1863, p. 370, fig. 386.

Rhynchonella (Stenocisma) billingsi Hall, Pal. New York, IV, 1867, p. 336, pl. 54, figs. 9–13.

Digitized by Google

Camarotœchia billingsi Hall—Continued.

Camarotœchia billingsi Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 192, pl. 57, fig. 3.

Loc. New York; Columbus, Ohio; Ontario.

Camarotœchia carica Hall. Hamilton (Dev.).

Rhynchonella (Stenocisma) carica Hall, Pal. New York, IV, 1867, p. 344, pl. 54A, figs. 21–23.

Camarotœchia carica Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 192.

Loc. Hamilton, Madison County, New York.

Camarotœchia carolina Hall. Corniferous (Dev.).

Rhynchonella (Stenocisma) carolina Hall, Pal. New York, IV, 1867, p. 337, pl. 34, figs. 14–19.

Rhynchonella carolina Meek, Pal. Ohio, I, 1873, p. 196, pl. 18, fig. 8.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 75, pl. 13, figs. 1–3, 34, 35.

Camarotœchia carolina Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 4–6.

Loc. Columbus and Sandusky, Ohio; Falls of Ohio.

Camarotœchia congregata (Conrad). Hamilton (Dev.).

Atrypa congregata Conrad, Fifth Ann. Rep. New York Geol. Survey, 1841, p. 55.

Rhynchonella (Stenocisma) congregata Hall, Pal. New York, IV, 1867, p. 341, pl. 54, figs. 44–59.

Camarotœchia congregata Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 15–27.

Loc. Fultonham, Summit, Onondaga, and Tinkers Falls, New York.

Camarotœchia contracta Hall. Portage-Waverly (Dev.-L. Carb.).

Atrypa contracta Hall, Geol. New York; Rep. Fourth Dist., 1843, tab. 66, figs. 2, 3.

Atrypa laticostata Hall (non Phillips), Ibidem, 1843, tab. 66, fig. 1.

Rhynchonella (Stenocisma) contracta Hall, Pal. New York, IV, 1867, p. 351, pl. 55, figs. 26–39.

Rhynchonella contracta Herrick, Bull. Denison Univ., III, 1887, p. 39, pl. 10, fig. 9;—Ibidem, IV, 1888, p. 23, pl. 11, fig. 21.

Camarotœchia contracta Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 28–32, 49.

Loc. New York; Meadville and Bradford, Pennsylvania; Licking County, Ohio.

Camarotœchia contracta saxatilis (Hall). Hamilton (Dev.).

Rhynchonella (Stenocisma) saxatilis Hall, Pal. New York, IV, 1867, p. 417, pl. 54A, figs. 44–51.

Loc. Rockford, Iowa.

Camarotœchia dotis Hall. Marcellus and Hamilton (Dev.).

Rhynchonella (Stenocisma) dotis Hall, Pal. New York, IV, 1867, p. 344, pl. 54A, figs. 11–20.—Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 246, pl. 8, figs. 10, 12;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 33.

Camarotœchia dotis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 40, 41.

Loc. Geneseo and York, New York; Columbus, Ohio; Rio Maecuru and R^o Curua and Erere, Brazil.

Camarotœchia(?) duplicata Hall. Chemung (Dev.).

Atrypa duplicata Hall, Geol. New York; Rep. Fourth Dist., 1843, tab. 67, fig. 2.

Rhynchonella (Stenocisma) duplicata Hall, Pal. New York, IV, 1867, p. 350, pl. 55, figs. 17–25.

Digitized by Google

Camarotœchia (?) duplicata Hall—Continued.

Rhynchonella duplicata Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 155, pl. 14, fig. 8.

Camarotœchia (?) duplicata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 36–39.

Loc. New York; Eureka district, Nevada.

Camarotœchia (Plethorhyncha) endlichi (Meek). ?Devonian.

Rhynchonella endlichi Meek, Bull. U. S. Geol. Survey Terr., 2d ser., 1, 1875, p. 46.—White, Twelfth Ann. Rep. U. S. Geol. Survey Terr., 1883, p. 133, pl. 36, fig. 2; pl. 33, fig. 4.

Loc. East of Animas River, Colorado.

Obs. This type of Rhynchonella occurs in eastern North America only in the Lower Devonian. It therefore seems probable that Meek's provisional reference to the Devonian is nearer correct than White's to the Lower Carboniferous.

Camarotœchia eximia Hall. Portage-Chemung (Dev.).

Atrypa eximia Hall, Geol. New York; Rep. Fourth Dist., 1843, tab. 66, fig. 4.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 829, fig. 682.

Rhynchonella (Stenocisma) eximia Hall, Pal. New York, IV, 1867, p. 348, pl. 55, figs. 1–8.—Kindle, Bull. American Pal., 6, 1896, p. 36.

Camarotœchia eximia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 44, 45.

Loc. Ithaca, New York; Pennsylvania.

Camarotœchia fringilla (Billings). Anticosti (Sil.).

Rhynchonella fringilla Billings, Pal. Fossils, I, 1862, p. 141, fig. 118.

Camarotœchia fringilla Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190, pl. 56, figs. 28–30.

Loc. Anticosti.

Camarotœchia glacialis (Billings). Anticosti (Sil.).

Rhynchonella glacialis Billings, Pal. Fossils, I, 1862, p. 143, fig. 120.

Camarotœchia glacialis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190.

Loc. Anticosti.

Camarotœchia horsfordi Hall. Marcellus and Hamilton (Dev.).

Rhynchonella horsfordi Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 87.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 152, pl. 14, fig. 3; pl. 15, fig. 6.

Rhynchonella (Stenocisma) horsfordi Hall, Pal. New York, IV, 1867, p. 339, pl. 54, figs. 24–32.

Camarotœchia horsfordi, Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 7–9.

Loc. Moscow, York, Geneseo, and Avon, New York; Eureka district, Nevada.

Camarotœchia(?) indianensis (Hall). Niagara (Sil.).

Rhynchonella indianensis Hall, Trans. Albany Institute, IV, 1863, p. 215;—Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 163, pl. 26, figs. 12–22;—Eleventh Rep. State Geol. Indiana, 1882, p. 306, pl. 26, figs. 12–22; pl. 27, figs. 4–6.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 76, pl. 33, figs. 18–20.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 42, pl. 3, figs. 17–28.

Loc. Waldron, Indiana; Louisville, Kentucky.

Camarotœchia marshallensis (A. Winchell). Marshall (L. Carb.).

Rhynchonella marshallensis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 408.—Herrick, Bull. Denison Univ, III, 1888, p. 40; IV, p. 23;—Geol. Ohio, VII, 1895, pl. 23, fig. 14.

Digitized by Google

Camarotœchia marsnallensis (A. Winchell)—Continued.

Camarotœchia marshallensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192.

Loc. Marshall, Michigan; Granville, etc., Ohio.

Camarotœchia(?) neglecta Hall. Clinton and Niagara (Sil.).

Atrypa neglecta Hall, Pal. New York, II, 1852, p. 70, pl. 23, fig. 4; p. 274, pl. 57, fig. 1.—Billings, Canadian Nat. Geol., I, 1856, p. 138, pl. 2, figs. 11, 12.

Rhynchonella neglecta Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 78.—Billings, Geology Canada, 1863, p. 315, fig. 325.—Meek, Pal. Ohio, I, 1873, p. 179, pl. 15, fig. 3.—Hall and Whitfield, Ibidem, II, 1875, p. 134, pl. 7, fig. 15.—Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 162, pl. 26, figs. 1–6;—Eleventh Rep. State Geol. Indiana, 1882, p. 305, pl. 26, figs. 1–6; pl. 27, fig. 3.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 37, pl. 4, figs. 3, 6–8.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 317, pl. 6, fig. 12.

Rhynchonella neglecta var. scobina Meek, American Jour. Sci., 3d ser., IV, 1872, p. 277.

Rhynchonella scobina Hall and Whitfield, Pal. Ohio, II, 1875, p. 116.—Foerste, Geol. Ohio, VII, 1895, p. 592.

Camarotœchia? neglecta Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190.

Loc. Reynales Basin, Lockport, etc., New York; Hamilton, Ontario; Dayton and Cedarville, Ohio; Hanover, Indiana; Wisconsin; Arisaig, Nova Scotia.

Camarotœchia obtusiplicata Hall. Niagara (Sil.).

Atrypa obtusiplicata Hall, Pal. New York, II, 1852, p. 279, pl. 58, fig. 2.

Rhynchonella obtusiplicata Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 78.

Camarotœchia obtusiplicata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190.

Loc. Lockport, New York.

Camarotœchia orbicularis Hall. Chemung (Dev.).

Rhynchonella orbicularis Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 88.

Rhynchonella (Stenocisma) orbicularis Hall, Pal. New York, IV, 1867, p. 353, pl. 55, figs. 40–46.

Camarotœchia orbicularis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 46–48, 50.

Loc. Chautauqua County, New York; Meadville, Pennsylvania.

Camarotœchia plena Hall. Chazy (Ord.).

Atrypa plena Hall, Pal. New York, I, 1847, p. 21, pl. 4 bis, fig. 7.—Billings, Canadian Nat. Geol., I, 1856, p. 207, figs. 17–19.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 817, fig. 592.

Atrypa plicifera Hall, Pal. New York, I, 1847, p. 22, pl. 4 bis, fig. 8.

Atrypa altilis Hall, Ibidem, 1847, p. 23, pl. 4 bis, fig. 9.

Rhynchonella plena, plicifera, and altilis Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, pp. 65, 66.

Rhynchonella plena Billings, Canadian Nat. Geol., IV, 1859, p. 444, fig. 22;—Geol. Canada, 1863, p. 126, fig. 50.

Camarotœchia plena and altilis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190.

Loc. Chazy, New York; Montreal and Ottawa, Canada.

Camarotœchia (Plethorhyncha) pleiopleura (Conrad). Oriskany (Dev.).

Atrypa pleiopleura Conrad, Fifth Ann. Rep. Geol. Survey New York, 1841, p. 55.

Rhynchonella pleiopleura Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 86, figs. 1–4;—Pal. New York, III, 1859, p. 440, pl. 102, figs. 3, 4.—Billings, Pal. Fossils, II, 1874, p. 38, figs. 19, 20.

Digitized by Google

Camarotœchia (Plethorhyncha) pleiopleura (Conrad)—Continued.

Plethorhyncha pliopleura Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 191.

Loc. Albany and Schoharie counties, New York; Indian Cove, Gaspé.

Camarotœchia prolifica Hall. Marcellus and Hamilton (Dev.).

Rhynchonella (Stenocisma) prolifica Hall, Pal. New York, IV, 1867, p. 343, pl. 54A, figs. 1–10.

Rhynchonella prolifica Tschernyschew, Mém. du Comité Géol. St. Petersburg, III, 1887, p. 89, pl. 14, fig. 6.

Camarotœchia prolifica Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 42, 43.

Loc. Fultonham and Cooperstown, New York; Russia.

Camarotœchia sageriana (A. Winchell). Marshall (L. Carb.).

Rhynchonella sageriana A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 407;—Ibidem, 1865, p. 122.—Herrick, Bull. Denison Univ., III, 1888, p. 39.

Camarotœchia sageriana Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192.

Loc. Marshall, Michigan; Weymouth, Ashland, Sciotoville, and Newark, Ohio; Hickman County, Tennessee.

Camarotœchia sappho Hall. Marcellus-Waverly (Dev.-L. Carb.).

Rhynchonella sappho Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 87.—Herrick, Bull. Denison Univ., III, 1888, p. 40, pl. 5, fig. 1; pl. 7, fig. 25;—Geol. Ohio, VII, 1895, pl. 21, fig. 1.

Rhynchonella (Stenocisma) sappho Hall, Pal. New York, IV, 1867, p. 340, pl. 54, figs. 33–43; var. pl. 55, figs. 47–52.

Camarotœchia sappho Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 10–14.

Loc. Leroy, Geneseo, and York, New York; Licking County, Ohio.

Camarotœchia (Plethorhyncha) speciosa (Hall). Oriskany (Dev.).

Rhynchonella speciosa Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 81;—Pal. New York, III, 1859, p. 444, pl. 103A, figs. 1–6.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 394, pl. 8, fig. 9.

Rhynchotrema speciosa Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 411.

Plethorhyncha speciosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 191, pl. 58, figs. 29–37.

Loc. Cumberland, Maryland; Jackson County, Illinois.

Camarotœchia stephani Hall. Portage and Chemung (Dev.).

Rhynchonella (Stenocisma) stephani Hall, Pal. New York, IV, 1867, p. 349, pl. 55, figs. 9–16.

Camarotœchia stephani Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192;—Ibidem, 1895, pl. 57, figs. 33–35.

Loc. Ithaca and Phillipsburg, New York; Bradford, Pennsylvania.

Camarotœchia tethys (Billings). Corniferous (Dev.).

Rhynchonella? tethys Billings, Canadian Jour., V, 1860, p. 270, figs. 20–22.

Rhynchonella tethys Billings, Geol. Canada, 1863, p. 370, fig. 387.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 152.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 83, pl. 13, figs. 25–33; pl. 31, figs. 22–25.

Rhynchonella (Stenocisma) tethys Hall, Pal. New York, IV, 1867, p. 335, pl. 54, figs. 1–8.

Camarotœchia tethys Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 192, pl. 57, figs. 1, 2.

Loc. County of Haldimand, Ontario; Stafford and Williamsville, New York; Columbus, Ohio; Falls of Ohio; Eureka district, Nevada.

Digitized by Google

Camarotœchia ventricosa Hall. Lower Helderberg (Dev.).

Rhynchonella ventricosa Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 78, figs. 1–6;—Pal. New York, III, 1859, p. 238, pl. 43, fig. 1.

Camarotœchia ventricosa Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 191.

Wilsonia ventricosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 58, figs. 13, 14.

Loc. Schoharie, Carlisle, and Cherry Valley, New York.

Camarotœchia whitei Hall. Niagara (Sil.).

Rhynchonella whitii Hall (non A. Winchell), Trans. Albany Institute, IV, 1863, p. 216.

Rhynchonella whitii Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 164, pl. 26, figs. 23–33;—Eleventh Rep. State Geol. Indiana, 1882, p. 307, pl. 26, figs. 23–33.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 39, pl. 4, figs. 1, 2, 4, 5.

Rhynchonella whitiana Miller, American Pal. Fossils, 2d ed., 1883, p. 297.

Camarotœchia? whitii Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 190.

Loc. Waldron and Osgood, Indiana.

Capulus lugubris Conrad=Discinisca lugubris.

CAPELLINIA Hall and Clarke. Genotype C. mira H. and C.

Capellinia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 248, pl. 70, figs. 6–14;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 847.

Capellinia mira Hall and Clarke. Niagara (Sil.).

Capellinia mira Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 249, pl. 70, figs. 6–14.

Loc. Vicinity of Milwaukee, Wisconsin.

CATAZYGA Hall and Clarke. Genotype Athyris headi Billings.

Catazyga Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 157, fig. 151;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 803.

Catazyga erratica Hall. Lorraine (Ord.).

Orthis? erratica Hall, Pal. New York, I, 1847, p. 288, pl. 79, fig. 5.

Athyris headi var. anticostiensis Billings, Pal. Fossils, I, 1862, p. 147, fig. 127.

Athyris headi var. borealis, Billings, Ibidem, 1862, p. 147, fig. 126.

Athyris borealis Billings, Geol. Canada, 1863, p. 212, fig. 216.

Athyris anticostiensis Billings, Ibidem, 1863, p. 212, fig. 215.

Zygospira anticostiensis Davidson, Suppl. British Sil. Brach., Palæontographical Soc., 1882, p. 127.

Zygospira erratica Davidson, Ibidem, 1882, p. 126.

Orthis erratica, var. Keesow, Ueber Sil. u. Devon. geschiebe Westpreussens, 1884, p. 246, pl. 2, fig. 10.

Catazyga headi vars. borealis and anticostiensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 54, figs. 27, 31–34.

Catazyga erratica Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 158, pl. 54, figs. 17–23.

Loc. Oswego County, New York; River Saguenay, Lake St. John, Canada; Anticosti; "Wesenberg Schict," Prussia.

Catazyga headi (Billings). Lorraine (Ord.).

Athyris headi Billings, Pal. Fossils, I, 1862, p. 147, fig. 125;—Geol. Canada, 1863, p. 212, fig. 214.

Zygospira headi Hall, Twenty-third Rep. New York State Cab. Nat. Hist., 1872, pl. 13, figs. 23–25 (extract pub. 1871).—Meek, Pal. Ohio, I, 1873, p. 127, pl. 11, fig. 1.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 59.—Davidson, Suppl. British Sil. Brach., Palæontographical Soc., 1882, p. 125.

Glassia schuchertana Ulrich, American Geologist, I, 1888, p. 186.

Glassia headi Miller, N. American Geol. Pal., 1889, p. 346.

Digitized by Google

Catazyga headi (Billings)—Continued.

Catazyga headi Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 158, fig. 151; pl. 54, figs. 24–26, 30.

Loc. St. Lawrence River, opposite Three Rivers; near St. Nicholas, St. Croix, and Becancour River, Quebec, Canada; Waynesville, etc., Ohio; Richmond and Versailles, Indiana. According to Mr. Ami, also in the Utica slate at Ottawa, Canada.

Catazyga uphami (Winchell and Schuchert). Trenton (Ord.).

Zygospira uphami Winchell and Schuchert, American Geol., IX, 1892, p. 291;—Minnesota Geol. Survey, III, p. 468, pl. 34, figs. 45–48.

Loc. Near Spring Valley and Wykoff, Minnesota.

CENTRONELLA Billings. Genotype Rhynchonella glansfagea Hall.

Centronella Billings, Canadian Nat Geol., IV, 1859, p. 131, figs. 1–5;—Canadian Jour., VI, 1861, p. 271.—Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 45, figs. 13–17;—American Jour. Sci., 2d ser., XXXV, 1863, p. 396.—Billings, Ibidem, XXXVI, 1863, p. 237.—Hall, Trans. Albany Institute, IV, 1863, pp. 134, 148.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 122.—Hall, Pal. New York, IV, 1867, p. 399.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 265;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 853.

Centronella(?) allei A. Winchell. Waverly (L. Carb.).

Centronella allii A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 123.

Cryptonella? allei Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 290.

Loc. Burlington, Iowa; Hamburg, Illinois; Summit County, Ohio.

Centronella alveata Hall. Onondaga (Dev.).

Rhynchonella? alveata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 124.

Centronella hecate Billings, Canadian Jour., VI, (May) 1861, p. 272, fig. 99;—Geol. Canada, 1863, p. 374, fig. 403.—Hall, Pal. New York, IV, 1867, p. 420, pl. 61A, figs. 27–29.—Ibidem, VIII, Pt. II, 1895, pl. 79, fig. 15.

Centronella alveata Hall, Pal. New York, IV, 1867, p. 401, pl. 61A, figs. 22–24.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 268, pl. 79, figs. 22–24.

Loc. New York; Cayuga, Ontario.

Obs. See C. impressa Hall.

Centronella anna Hartt=Harttina anna.

Centronella(?) arcei A. Ulrich. Devonian.

Centronella? arcei Ulrich, N. Yahrb. f. Mineral., Beilageband, VIII, 1892, p. 53, pl. 5, figs. 5–9.

Loc. Icla, and near Pulquina, Bolivia.

Centronella billingsiana Meek and Worthen=Whitfieldella billingsiana.

Centronella(??) crassicardinalis Whitfield. Warsaw (L. Carb.).

Centronella crassicardinalis Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 55, pl. 6, figs. 50–52.—Hall, Twelfth Rep. State Geol. Indiana, XXIX, 1883, figs. 50–52.

Loc. Spergen Hill, Indiana.

Obs. This species is not well established and is based upon a single ventral valve. Compare with Athyris densa.

Centronella(?) flora A. Winchell. Waverly (L. Carb.).

Centronella? flora A. Winchell, Proc. American Phil. Soc., XII, 1870, p. 254.

Loc. Sciotoville, Ohio.

Digitized by Google

Centronella glansfagea Hall. Oriskany-Corniferous (Dev.).

Rhynchonella glansfagea Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 125, figs. 1–6.

Centronella glansfagea Billings, Canadian Nat. Geol., IV, 1859, p. 132, figs. 1–5;—Canadian Jour., VI, 1861, p. 271, fig. 97;—Geol. Canada, 1863, p. 374, fig. 405.—Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, pp. 45–47;—Pal. New York, IV, 1867, p. 399, pl. 61A, figs. 1–21, 25, 26.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 153, pl. 31, figs. 14–17.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 268, fig. 180; 180; pl. 79, figs. 1–14, 17, 21.

Loc. Albany and Schoharie counties, New York; Cayuga, Ontario; Falls of Ohio; Michigan.

Obs. In the American Museum of Natural History this species is labeled Atrypa naviculoides Conrad. The writer has not been able to find this description. It may be one of Conrad's manuscript names.

Centronella glaucia Hall. Hamilton (Dev.).

Centronella glaucia Hall, Pal. New York, IV, 1867, p. 403, pl. 61A, figs. 39, 40.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 269.

Loc. Schoharie, New York.

Centronella hecate Billings=C. alveata.

Centronella impressa Hall. Hamilton (Dev.).

Centronella impressa Hall, Fourteenth Rep. New York State Cab. Nat. Hist., (July or August) 1861, p. 102;—Fifteenth Rep., Ibidem, 1862, pl. 3, figs. 1–5.—Billings, Canadian Nat. Geol., VII, 1862, p. 392.—Hall, Pal. New York, IV, 1867, p. 402, pl. 61A, figs. 30–38.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 269, pl. 79, figs. 16, 18–20.

Loc. Bellona, York, Pavilion, and Hamburg, New York.

Obs. Billings says this species is the same as C. hecate (=C. alveata).

Centronella julia A. Winchell=Romingerina julia.

Centronella margarida Derby=Trigeria margarida.

Centronella (?) navicella Hall. Chemung (Dev.).

Terebratula navicella Hall, Pal. New York, IV, 1867, p. 391, pl. 60, figs. 38–44.

Centronella (?) navicella Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 79, figs. 40–42.

Loc. Rockford, Iowa.

Centronella ovata Hall. Upper Helderberg (Dev.).

Centronella ovata Hall, Pal. New York, IV, 1867, p. 419, pl. 61A, figs. 47–49.

Loc. Cayuga, Ontario.

Centronella(?) silvetii A. Ulrich. Devonian.

Centronella silvetii A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 51, pl. 4, figs. 15a–15d.

Loc. Chahuarani, Bolivia.

Centronella tumida Billings. Oriskany and Corniferous (Dev.).

Centronella tumida Billings, Canadian Jour., VI, 1861, p. 272, fig. 98;—Geol. Canada, 1863, p. 374, fig. 404.

Loc. Cayuga and Port Colbourne, Ontario.

CHARIONELLA Billings. Genotype Atrypa scitula Hall.

Charionella Billings, Canadian Jour., VI, 1861, pp. 148, 274, figs. 101, 102.—Hall, Sixteenth Rep. New York State Cab. Nat Hist., 1863, p. 40;—American Jour. Sci., n. ser., XXXV, 1863, p. 396.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 78;—Thirteenth Rep. New York State Geologist, 1895, p. 775.

Digitized by Google

Charionella circe Billings=C. scitula.
Charionella doris Billings=Meristella doris.
Charionella hyale Billings=Whitfieldella hyale.
Charionella rostrata Billings=Meristella rostrata.

Charionella scitula Hall. Corniferous (Dev.).

Atrypa scitula Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 171, fig. 1.
Athyris? scitula Billings, Canadian Jour., V, 1860, p. 278, figs. 35–38.
Charionella circe Billings, Ibidem, VI, 1861, p. 273, fig. 100;—Geol. Canada, 1863, p. 374, fig. 400.
Meristella scitula Hall, Pal. New York, IV, 1867, p. 302, pl. 47, figs. 34–38.
Meristella circe Miller, N. American Geol. Pal., 1889, p. 354.
Charionella scitula Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 78, pl. 42, figs. 17–19.
Loc. Williamsville and Clarence Hollow, New York; Columbus, Ohio (Whitfield); county of Haldimand, Ontario.

CHONETES Fischer de Waldheim. Genotype Orthis striatella Dalman.

Chonetes Fischer de Waldheim, Oryctographie du Gouvernement de Moscow, Pt. II, 1837, p. 134.—Hall, Pal. New York, II, 1852, p. 64.—Billings, Canadian Jour., VI, 1861, p. 349.—Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. Knowl., 172, 1864, p. 22.—Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 242;—Pal. New York, IV, 1867, p. 115.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 122.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1886, p. 66.—Hall and Clarke, Pal. New York, VIII, Pt. 1, 1892, p. 303;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 292.

Chonetes acutiradiatus Hall. Corniferous (Dev.).

Strophomena acutiradiata Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 171, fig. 3.
Chonetes acutiradiata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 117;—Pal. New York, IV, 1867, p. 120, pl. 20, fig. 5;—Second Ann. Rep. New York State Geol., 1883, pl. 47, fig. 8.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 66, pl. 18, figs. 18–20.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, fig. 8.
Loc. Williamsville, Stafford, etc., New York; Columbus, Ohio; Falls of Ohio.

Chonetes amazonicus Derby. Upper Carboniferous.

Chonetes amazonica Derby, Bull. Cornell Univ., I, 1874, p. 41, pl. 6, figs. 3, 12, 19; pl. 9, figs. 8, 9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15B, fig. 13.
Loc. Itaituba, Brazil.

Chonetes antiope Billings. Lower Devonian.

Chonetes anitope Billings, Pal. Fossils, II, 1874, p. 19.
Loc. Mount Jolli and Percé, Nova Scotia.

Chonetes arcei A. Ulrich. Middle Devonian.

Chonetes arcei A. Ulrich, N. Jahrb. f. Mineral., Beilageband VIII, 1892, p. 77, pl. 4, figs. 35, 36.
Loc. Chahuarani, Icla, and Tarabuco, Bolivia.

Chonetes arcuatus Hall. Corniferous (Dev.).

Chonetes arcuata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 116;—Pal. New York, IV, 1867, p. 119, pl. 20, fig. 7;—Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 15, 35, 36.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, figs. 15, 35, 36.
Loc. Williamsville, Clarence Hollow, etc., New York; Columbus, Ohio.

Digitized by Google

Chonetes armata Norwood and Pratten (non Bouchard)=C. pusilus.

Chonetes canadensis Billings. Lower Devonian.

Chonetes canadensis Billings, Pal. Fossils, II, 1874, p. 17, fig. 7.

Loc. Percé, Nova Scotia.

Chonetes complanata Hall=Chonostrophia complanata.

Chonetes comstockei Rathbun. Middle Devonian.

Chonetes comstockii Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 250, pl. 9, figs. 5, 14, 18, 19, 31;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 18.

Loc. Province of Para, Brazil.

Chonetes cornutus (Hall). Clinton (Sil.).

Strophomena cornuta Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 73, fig. 3.

Chonetes cornuta de Koninck, Recher. Animaux Foss., Pt. I, 1847, p. 200, pl. 20, fig. 3.—Hall, Pal. New York, II, 1852, p. 64, pl. 21, fig. 10;—Second Ann. Rep. New York State Geol., 1883, pl. 47, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, fig. 1.

Loc. Wayne County, New York.

Chonetes coronatus (Conrad). Hamilton (Dev.).

Strophomena carinata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 257, pl. 14, fig. 13.

Strophomena syrtalis Conrad, Ibidem, 1842, p. 253, pl. 14, fig. 1.

Chonetes littoni Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 25, pl. 2, fig. 4.

Chonetes maclurea Norwood and Pratten, Ibidem, 1854, p. 28, pl. 2, fig. 8.

Chonetes tuomyi Norwood and Pratten, Ibidem, 1854, p. 28, pl. 2, fig. 9.

Chonetes martini Norwood and Pratten, Ibidem, 1854, p. 29, pl. 2, fig. 10.

Chonetes coronata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 146, figs. 1, 2;—Pal. New York, IV, 1867, p. 133, pl. 21, figs. 9-12.—Whitfield, Geol. Wisconsin, IV, 1882, p. 327, pl. 25, fig. 16.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 10, 11, 24, 26, 33, 39, 41, 43.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, figs. 10, 11, 24, 26, 33, 39, 41, 43.

Loc. New York; Pennsylvania; near Arkona, Ontario; Bakeoven, Illinois; Milwaukee, Wisconsin.

Obs. In the Illinois State collection there are specimens of C. maclurea and C. littoni which are not specifically distinct from C. coronatus Conrad. In the American Museum of Natural History the writer has seen specimens of C. tuomyi and C. martini labeled as varieties of C. coronatus.

Chonetes curuaensis Rathbun. Middle Devonian.

Chonetes curuaensis Rathbun, Proc. Boston Soc. Nat. Sci., XX, 1879, p. 21.

Loc. Province of Para, Brazil.

Chonetes dawsoni Billings=Chonostrophia dawsoni.

Chonetes deflecta Hall=C. vicinus.

Chonetes emmetensis A. Winchell. Hamilton (Dev.).

Chonetes emmetensis A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 92.

Loc. Grand Traverse Region, Michigan.

Chonetes falklandicus Morris and Sharpe. Lower Devonian.

Chonetes falklandica Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 274, pl. 10, fig. 4.—De Koninck, Recher. Animaux Foss., Pt. I, 1847, p. 204, pl. 20, fig. 4.—Von Ammon, Zeits. d. Gessels. für Erdk., Berlin, XXVIII, 1893, p. 360, fig. 5.

Loc. Falkland Islands; Taquarassu, Matto Grosso, Brazil.

Digitized by Google

Chonetes filistriatus Walcott. Lower Devonian.

Chonetes filistriata Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 127, pl. 13, fig. 15.

Loc. Eureka district, Nevada.

Chonetes fischeri Hall=Chonopectus fischeri.

Chonetes flemingi Norwood and Pratten=C. variolatus.

Chonetes freitassii Rathbun. Middle Devonian.

Chonetes species Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 253.

Chonetes freitassii Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 18.

Loc. Province of Para, Brazil.

Chonetes geinitziana Waagen, and Miller=C. glaber.

Chonetes geniculatus White. Kinderhook (L. Carb.).

Chonetes geniculata White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 29.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 116;—Proc. American Phil. Soc., XI, 1870, p. 250.

Chonetes geniculatus Keyes, Geol. Survey Missouri, V, 1895, p. 53, pl. 38, fig. 3.

Loc. Hamburg, Illinois; Clarksville, Missouri; Rockford, Indiana; Rockville, Ohio.

Obs. Compare with C. ornatus Shumard.

Chonetes gibbosa Hall=C. vicinus.

Chonetes glabra Hall (non Geinitz)=C. lineatus.

Chonetes glaber Geinitz. Upper Carboniferous.

Chonetes glabra Geinitz, Carbon u. Dyas in Nebraska, 1866, p. 60, pl. 4, figs. 15–18.—Toula, Sitzb. der Kais. Akad. der Wissensch., Wien, LIX, 1869, p. 10.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 171, pl. 4, fig. 10; pl. 8, fig. 8.—Derby, Bull. Cornell Univ., I, 1874, p. 43, pl. 8, figs. 11, 14, 15, 19;—Bull. Mus. Comp. Zool., III, 1876, p. 280.

Chonetes geinitziana Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 621.

Chonetes lævis Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 229, pl. 12, fig. 3;—Geol. Survey Missouri, V, 1895, p. 55, pl. 37, fig. 5.

Chonetes geinitzianus Miller, N. American Geol. Pal., 1889, p. 339.

Loc. Nebraska City, Nebraska; Kansas; Iowa; Illinois; Bomjardim and Itaituba, Brazil; Yampopata and Cochabamba, Bolivia.

Chonetes granulifer Owen. Upper Carboniferous.

Chonetes granulifera Owen, Geol. Rep. Iowa, Wisconsin, Minnesota, 1852, p. 583, pl. 5, fig. 12.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 24.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 170, pl. 4, fig. 9; pl. 6, fig. 10; pl. 8, fig. 7.—White, Wheeler's Geogr. Geol. Survey west 100 Merid., 1875, p. 122, pl. 9, fig. 8.—Keyes, Geol. Survey Missouri, V, 1895, p. 56.

Chonetes smithii Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 24, pl. 2, fig. 2.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 570, pl. 25, fig. 11.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15B, fig. 12.

Chonetes mucronata Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1858, p. 262;—Pal. Upper Missouri, Smithsonian Cont. to Knowl., 172, 1864, p. 22, pl. 1, fig. 5.—Geinitz, Carbon u. Dyas in Nebraska, 1866, p. 58, pl. 4, figs. 12–14.—Toula, Sitzungsb. der Kais. Akad. der Wissensch., Wein, LIX, 1869, p. 10.

Chonetes granuliferus Beecher, American Jour. Sci., 3d ser., XLI, 1891, p. 357, pl. 17, fig. 15.

Loc. Mouth of Keg Creek, Iowa; Illinois; Kansas; Missouri; Alabama; Kanab Canyon, Arizona; Cochabamba, Bolivia.

Digitized by Google

Chonetes hemisphericus Hall. Upper Helderberg (Dev.).

Chonetes hemispherica Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 116, figs. 1-3.—Billings, Canadian Jour., VI, 1861, p. 349, figs. 121-123; Geol. Canada, 1863, p. 368, fig. 380.—Hall, Pal. New York, IV, 1867, p. 118, pl. 20, fig. 6.—Nicholson, Pal. Prov. Ontario, 1873, p. 75.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 123.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, fig. 14.

Loc. Schoharie, etc., New York; Eureka district, Nevada; Ontario, Canada.

Chonetes herbert-smithi Rathbun. Middle Devonian.

Chonetes herbert-smithi (Hartt MS.) Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 251, pl. 10, figs. 39-42, 44-47;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 20.

Loc. Province of Para, Brazil.

Chonetes illinoisensis Worthen. Burlington (L. Carb.).

Chonetes logani Hall (non N. and P.), Geol. Survey Iowa, I, Pt. II, 1858, p. 598, pl. 12, figs. 1, 2.

Chonetes illinoiensis Worthen, Trans. St. Louis Acad. Sci., I, 1860, p. 571.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 5;—Ibidem, 1865, p. 116.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 505, pl. 15, fig. 8.—Herrick, Bull. Denison Univ., III, 1888, p. 35, pl. 3, fig. 21.

Loc. Burlington, Iowa; Jersey County, Illinois; Rockford, Indiana; Licking County, Ohio.

Chonetes iowensis Owen=Pholidostrophia iowensis.

Chonetes koninckianus Norwood and Pratten. Middle Devonian.

Chonetes koninckiana Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 30, pl. 2, fig. 11.

Loc. Jonesboro, Union County, Illinois.

Chonetes lævis Keyes=C. glaber Geinitz.

Chonetes laticosta Hall=C. mucronatus.

Chonetes lepidus Hall. Marcellus-Chemung (Dev.).

Chonetes lepida Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 148;—Pal. New York, IV, 1867, p. 142, pl. 22, figs. 12, 13.—Clarke, Bull. U. S. Geol. Survey, 16, 1885, pp. 24, 32.

Loc. Cayuga Lake, etc., New York; Meadville, Pennsylvania.

Chonetes lineatus (Conrad). Corniferous (Dev.).

Strophomea lineata Conrad, Third Ann. Rep. Geol. Survey New York, 1839, p. 64.—Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 139, fig. 6 (should be 5a).—Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 175, fig. 8.

Chonetes glabra Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 117, figs. 1-8.

Chonetes lineata Hall, Pal. New York, IV, 1867, p. 121, pl. 20, fig. 3;—Second Ann. Rep. New York State Geol., 1883, pl. 47, fig. 34.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, fig. 34.

Loc. Cayuga Lake, etc., New York.

Chonetes littóni Norwood and Pratten=C. coronatus.

Chonetes logani Hall (non Nor. and Prat.)=C. illinoisensis.

Chonetes logani Norwood and Pratten. Kinderhook-Burlington (L. Carb.).

Chonetes logani Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 30, pl. 2, fig. 12.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 116.—Hall, Pal. New York, IV, 1867, pl. 22, figs. 23, 26-28;—Second Ann. Rep. New York State Geol., 1883, pl. 47, fig. 25.—Herrick, Bull. Denison Univ., III, 1888, p. 35, pl. 3, fig. 12; pl. 7, fig. 22.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, fig. 25.

Loc. Burlington, Iowa; Quincy, Illinois; Licking County, Ohio.

Digitized by Google

Chonetes logani aurora Hall. Tully-Burlington (Dev.-L. Carb.).

Chonetes logani var. aurora Hall, Pal. New York, IV, 1867, p. 137, pl. 22, figs. 16–18;—Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 9, 18.—Whiteaves, Cont. to Canadian Pal., I, 1891, p. 215, pl. 29, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, figs. 9, 18.

Chonetes aurora Williams, Bull. Geol. Soc. America, I, 1890, p. 491, pl. 12, figs. 10, 11.

Loc. Tully and Deruyter, New York; Athabasca, Mackenzie, and Red Deer rivers, Northwest Territory, Canada; Cuyahoga and Licking counties, Ohio; Burlington, Iowa.

Chonetes loganensis Hall and Whitfield. Kinderhook (L. Carb.).

Chonetes loganensis Hall and Whitfield, King's Geol. Expl. 40th Paral., IV, 1877, p. 253, pl. 4, fig. 9.

Loc. Logan Canyon, Wahsatch Range, Utah.

Chonetes maclurea Norwood and Pratten=C. coronatus.

Chonetes macrostriata Walcott=Stropheodonta macrostriata.

Chonetes manitobensis Whiteaves. Upper Devonian.

Chonetes manitobensis Whiteaves, Cont. to Canadian Pal., I, 1892, p. 281, pl. 37, figs. 1, 2.

Loc. Manitoba Island, Lake Manitoba, Canada.

Chonetes martini Norwood and Pratten=C. coronatus.

Chonetes melonicus Billings. Oriskany (Dev.).

Chonetes melonica Billings, Pal. Fossils, II, 1874, p. 15, fig. 6.

Loc. Little Gaspé, Quebec, Canada.

Chonetes mesolobus Norwood and Pratten. Upper Carboniferous.

Chonetes mesoloba Nor. and Prat., Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 27, pl. 2, fig. 7.—White, Wheeler's Geogr. Geol. Expl. Survey west 100 Merid., 1875, p. 123, pl. 9, fig. 7.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 47, fig. 22.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 228.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, fig. 22.

Loc. Belleville, Illinois; Charboniere, Missouri; Flint Ridge, Ohio; New Mexico; Arizona.

Chonetes michiganensis Stevens. Upper Carboniferous.

Chonetes michiganensis Stevens, American Jour. Sci., 2d ser., XXV, 1858, p. 263.

Loc. Battle Creek, Michigan.

Chonetes millipunctata Meek and Worthen=Aulacorhynchus millipunctatum.

Chonetes minima Hall (non Sowerby)=C. undulatus.

Chonetes mucronata Meek and Hayden (non Hall)=C. granulifer.

Chonetes mucronatus Hall. Oriskany-Hamilton (Dev.).

Strophomena mucronata Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 180, fig. 3.

Chonetes laticosta Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 119.—Billings, Pal. Fossils, II, 1874, p. 20.

Chonetes mucronata Hall, Pal. New York, IV, 1867, p. 124, pl. 20, fig. 1; pl. 21, fig. 1.—Nicholson, Pal. Prov. Ontario, 1873, p. 74.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 6, 7.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, figs. 6, 7.

Chonetes mucronata? Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 124.

Loc. New York; Cayuga, Ontario; Gaspé; Eureka district, Nevada.

Obs. See C. stübeli.

Digitized by Google

Chonetes multicosta A. Winchell. Kinderhook and Burlington (L. Carb.).

Chonetes multicosta A Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 5;—Proc. American Phil. Soc., XII, 1870, p. 250.

Loc. Burlington, Iowa; Hickman and Maury counties, Tennessee.

Chonetes muricata Hall=Strophalosia muricata.

Chonetes nana Norwood and Pratten (non de Verneuil)=C. yandellanus.

Chonetes novascoticus Hall. Arisaig and Niagara (Sil.).

Chonetes novascotica Hall, Canadian Nat. Geol., V, 1860, p. 144, fig. 2.—Dawson, Acadian Geol., 3d ed., 1878, p. 595, fig. 199.—Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 155, pl. 22, figs. 11-14;—Eleventh Rep. State Geol. Indiana, 1882, p. 293, pl. 22, figs. 11-14.

Loc. Arisaig, Nova Scotia; Waldron, Indiana.

Chonetes onettianus Rathbun. Middle Devonian.

Chonetes onettiana Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 253, pl. 10, figs. 43, 48.

Loc. Province of Para, Brazil.

Chonetes ornatus Shumard. Chouteau (L. Carb.).

Chonetes ornata Shumard, Geol. Rep. Missouri, 1855, p. 202, Pl. C, fig. 1.—Keyes, Geol. Survey Missouri, V, 1895, p. 53, pl. 38, fig. 2.

Loc. Louisiana and Hannibal, Missouri.

Obs. See C. geniculatus White.

Chonetes parvus Shumard. Upper Carboniferous.

Chonetes parva Shumard, Geol. Rep. Missouri, 1855, p. 201.

Loc. Boone County, Missouri.

Obs. Keyes says this species is a synonym for C. flemingi=C. variolatus.

Chonetes permianus Shumard. Upper Carboniferous.

Chonetes permiana Shumard, Trans. St. Louis Acad. Sci., I, 1859, p. 390.

Loc. Mouth of Delaware Creek, Texas.

Chonetes planumbonus Meek and Worthen. Keokuk (L. Carb.).

Chonetes planumbona Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 450;—Geol. Survey Illinois, II, 1866, p. 253, pl. 18, fig. 1.

Loc. Monroe County, Illinois; Crawfordsville, Indiana; Kings Mountain, Kentucky.

Chonetes platynotus White. Upper Carboniferous.

Chonetes platynota White, Wheeler's Geogr. Geol. Expl. Survey west 100 Merid., Prel. Rep., 1874, p. 19;—Ibidem, Final Rep., IV, 1875, p. 121, pl. 9, fig. 6.

Loc. Santa Fe, New Mexico; near Salt Lake, Utah.

Chonetes pulchellus A. Winchell. Waverly (L. Carb.).

Chonetes pulchella A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 410;—Ibidem, 1865, p. 115;—Proc. American Phil. Soc., XII, 1870, p. 250.—Herrick, Bull. Denison Univ., III, 1888, p. 37, pl. 3, fig. 14.

Loc. Moscow, Hillsdale County, Michigan; Trumbull, Summit, and Licking counties, Ohio; Shafers, Pennsylvania; Hickman County, Tennessee.

Chonetes punctatus Simpson. Lower Helderberg (Dev.).

Chonetes punctata Simpson, Trans. American Phil. Soc., n. ser., XVI, 1889, p. 438, fig. 3.

Loc. Hazardville, Carbon County, Pennsylvania.

Chonetes pusillus Hall. Hamilton (Dev.).

Chonetes armata Norwood and Pratten (non Bouchard), Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 28.

Digitized by Google

Chonetes pusillus Hall—Continued.

Chonetes pusilla Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 149;—Pal. New York, IV, 1867, p. 128, pl. 21, fig. 6.—Meek, Trans. Chicago Acad. Sci., I, 1868, p. 93, pl. 13, fig. 2.

Loc. Bakeoven, Illinois; Fort Resolution, Great Slave Lake, British America.

Obs. In the Illinois State collection there is a specimen of C. armatus N. and P. with an old label attached. This specimen is identical with C. pusillus Hall.

Chonetes reversa Whitfield=Chonostrophia reversa.

Chonetes rücki A. Ulrich. Middle Devonian.

Chonetes rücki A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 79, pl. 5, figs. 1, 2.

Loc. Chahuarani, Icla, and Tarabuco, Bolivia.

Chonetes sarcinulatus Norwood and Pratten.

Chonetes sarcinulata Norwood and Pratten (non Schlotheim), Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 28.

Obs. It is impossible to point out the American representative intended by these authors for this species.

Chonetes scitulus Hall. Marcellus–Chemung (Dev.).

Chonetes scitula Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 147;—Pal. New York, IV, 1867, p. 130, pl. 21, fig. 4;—Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 3, 4, 27, 32, 40, 44.—Herrick, Bull. Denison Univ., III, 1888, p. 36, pl. 1, fig. 4.—Whitfield, Annals New York Acad. Sci., V, 1891, p. 548, pl. 11, fig. 10.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, figs. 3, 4, 27, 32, 40, 44.—Whitfield, Geol. Ohio, VII, 1895, p. 443, pl. 7, fig. 10.—Kindle, Bull. American Pal., 6, 1896, p. 37.

Chonetes scitulus Beecher, American Jour. Sci., XLI, 1891, p. 357, pl. 17, fig. 14.

Loc. Moscow, Hamburg, etc., New York; Meadville, Pennsylvania; Delaware and Licking counties, Ohio.

Chonetes setigerus (Hall). Marcellus-Waverly (Dev.-L. Carb.).

Strophomena setigera Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 180, fig. 2; p. 222, fig. 3.

Chonetes setigera de Koninck, Recher. Animaux Foss., I, 1847, p. 215, pl. 20, fig. 7.—Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 150;—Pal. New York, IV, 1867, p. 129, pl. 21, fig. 2; p. 142, pl. 22, figs. 1–5;—Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 2, 5, 19.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 125.—Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 24.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, figs. 2, 5, 19.

Chonetes setigera? A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 411.

Loc. New York; Meadville, Pennsylvania; Ohio; Union City, Branch County, Michigan; Eureka district, Nevada.

Chonetes shumardianus de Koninck. Keokuk (L. Carb.).

Chonetes shumardiana de Koninck, Recher. Animaux Foss., Pt. I, 1847, p. 192, pl. 20, fig. 1.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 24.

Loc. The Knobs, Jefferson County, Kentucky.

Chonetes smithii Norwood and Pratten=C. granulifer.

Chonetes striatellus (Dalman). Silurian.

Orthis striatella Dalman, Kgl. Svens. Vetens.-Akad. Handl., 1828, p. 111, pl. 1, fig. 5.

Chonetes striatella Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 595.

Loc. Europe; Cape Louis Napoleon, lat. 79° 38′.

Digitized by Google

Chonetes stübeli A. Ulrich. Middle Devonian.

Chonetes stübeli A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 80, pl. 5, figs. 3, 4.

Loc. Rio Sicasica, Bolivia.

Obs. Probably the same as C. mucronatus.

Chonetes subquadratus Nettelroth. Hamilton (Dev.).

Chonetes subquadrata Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 67.

Loc. Falls of Ohio.

Chonetes tenuistriatus Hall. Arisaig (Sil.).

Chonetes tenuistriata Hall, Canadian Nat, Geol., V, 1860, p. 145, fig. 3.—Dawson, Acadian Geol., 3d ed., 1878, p. 596, fig. 200.

Loc. East River, Nova Scotia.

Chonetes tumidus Herrick. Waverly (L. Carb.).

Chonetes tumidus Herrick, Bull. Denison Univ., III, 1888, p. 36, pl. 2, fig. 21.

Loc. Moots Run, Licking County, Ohio.

Chonetes tuomyi Norwood and Pratten=C. coronatus.

Chonetes undulatus Hall. Niagara (Sil.).

Chonetes minima Hall (non Sowerby), Twenty-eighth Rep. New York State Mus. Nat. Hist., Doc. ed., 1876, pl. 22, fig. 15.

Chonetes undulata Hall, Ibidem, 1879, p. 155, pl. 22, fig. 15;—Eleventh Rep. State Geol. Indiana, 1882, p. 294, pl. 22, fig. 15.

Loc. Waldron, Indiana.

Chonetes variolatus (d'Orbigny). Upper Carboniferous.

Leptæna variolata d'Orbigny, Voyage dans l'Amérique Meridionale; Paléontologie, 1842, p. 49.

Productus variolata d'Orbigny, Ibidem, 1842, pl. 4, figs. 10, 11.

Chonetes variolata de Koninck, Recher. Animaux Foss., Pt. I, 1847, p. 206, pl. 20, fig. 2.—Hall, Stansbury's Expl. Great Salt Lake, 1852, p. 410, pl. 3, fig. 1.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 28.

Chonetes flemingi Norwood and Pratten, Ibidem, 1854, p. 26, pl. 2, fig. 5.—Geinitz, Carbon u. Dyas in Nebraska, 1866, p. 59.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15B, fig. 11.—Keyes, Geol. Survey Missouri, V, 1895, p. 54, pl. 38, fig. 6.

Loc. Yarbichambi, Bolivia; Guernsey, etc., Ohio; Illinois; Missouri; Kansas; Nebraska.

Obs. Compare with C. parvus.

Chonetes verneuilianus Norwood and Pratten. Upper Carboniferous.

Chonetes verneuiliana Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 26, pl. 2, fig. 6.—Newberry, Ives' Rep. Colorado River of the West, 1861, p. 128.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 170, pl. 1, fig. 10.—Hall, Second Rep. New York State Geol., 1883, pl. 47, figs. 20, 21.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 128, pl. 25, figs. 7, 8.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, figs. 20, 21.

Loc. Carboniere, Missouri; Indiana; Illinois; Missouri; Kansas; Nebraska; banks of Colorado River.

Chonetes verneuilianus utahensis Meek. Upper Carboniferous.

Chonetes verneuiliana var. utahensis Meek, Simpson's Rep. Expl. Great Basin, Ter. Utah, 1876, p. 348, pl. 2, fig. 2.

Loc. Near Humboldt Mountains, Utah.

Digitized by Google

Chonetes vicinus (Castelnau). Hamilton (Dev.).

Leptæna vicina Castelnau, Systeme Sil. l'Amérique Septentrionale, 1843, p. 39, pl. 14, fig. 9.

Chonetes vicina de Koninck, Recher. Animaux Foss., Pt. I, 1847, p. 203.

Chonetes deflecta Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 149;—Pal. New York, IV, 1867, p. 126, pl. 21, figs. 7, 8;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 47, fig. 28.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 24, pl. 2, fig. 8.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 16, fig. 28.

Chonetes gibbosa Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 145.

Loc. Ontario County, New York; Columbus, Ohio; Wisconsin; Eureka district, Nevada.

Obs. Castelnau's specimens are from "Ontario County, New York." His figures are good and can not be compared with any other species than the well-known C. deflectus Hall, a species occurring abundantly in Ontario County.

Chonetes yandellanus Hall. Corniferous (Dev.).

Chonetes nana de Koninck (non de Verneuil), Recher. Animaux Foss., Pt. I, 1847, p. 213.—Norwood and Pratten (non de Verneuil), Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 28.

Chonetes yandellana Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 118;—Pal. New York, IV, 1867, p. 123, pl. 20, fig. 4.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 68, pl. 17, figs. 16–19; pl. 31, figs. 20, 30.

Loc. Falls of Ohio; Columbus, Ohio.

CHONOPECTUS Hall and Clarke. Genotype Chonetes fischeri N. and P.

Chonopectus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 312;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 295.

Chonopectus fischeri (Norwood and Pratten). Kinderhook and Burlington (L. Carb.).

Chonetes fischeri Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 25, pl. 2, fig. 3.—Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 517, pl. 7, fig. 1;—Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 17, 31.

Chonopectus fischeri Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 312, pl. 15B, figs. 20–23; pl. 16, figs. 17, 31.

Loc. Burlington, Iowa; Warren, Pennsylvania.

CHONOSTROPHIA Hall and Clarke. Genotype Chonetes reversa Whitfield.

Chonostrophia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 310;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 294.

Chonostrophia complanata Hall. Oriskany (Dev.).

Chonetes complanata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 56;—Pal. New York, III, 1859, p. 418, pl. 93, fig. 1;—Second Ann. Rep. New York State Geol., 1883, pl. 47, figs. 13, 29.

Chonostrophia complanata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 311, pl. 16, figs. 13, 29.

†Strophomena sp. A, A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 70, pl. 14, fig. 24 (†23).

Loc. Albany and Schoharie counties, New York; Cayuga, Ontario; Cumberland, Maryland; †Bolivia.

Chonostrophia dawsoni (Billings). Lower Devonian.

Chonetes dawsoni Billings, Pal. Fossils, II, 1874, p. 18, fig. 8.

Chonostrophia dawsoni Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 311.

Loc. Gaspé and Percé, Quebec, Canada.

Digitized by Google

Chonostrophia helderbergiæ Hall. Lower Helderberg (Dev.).

Chonostrophia helderbergia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 311, 353, pl. 15B, fig. 14.

Loc. Albany County, New York.

Chonostrophia reversa (Whitfield). Corniferous (Dev.).

Chonetes reversa Whitfield, Annals New York Acad. Sci., II, 1882, p. 213;—Ibidem, V, 1891, p. 549, pl. 11, figs. 8, 9;—Geol. Ohio, VII, 1895, p. 443, pl. 7, figs. 8, 9.

Chonostrophia reversa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 311, pl. 15B, figs. 15–19;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 176, pl. 4, fig. 5.

Loc. Columbus and Delaware, Ohio; Union Springs, New York; Cayuga, Ontario.

CHRISTIANIA Hall and Clarke. Genotype Leptæna subquadrata Hall.

Christiania Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 298;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 290.

Christiania subquadrata Hall. Lower Helderberg (Dev.).

Leptæna subquadrata Hall, Second Ann. Rep. New York State Geol., 1883, pl. 46, figs. 32, 33.

Christiania subquadrata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 298, 351, pl. 15, figs. 32, 33; pl. 15A, fig. 36; pl. 20, figs. 18–20.

Loc. Perry and Blount counties, Tennessee.

CISTELLA Gray. Genotype Terebratula cuneata Risso.

Cistella Gray, Brit. Mus. Cat. Brach., p. 114.

Cistella beecheri Clark. Upper Cretaceous.

Cistella beecheri Clark, Johns Hopkins Univ. Circ., XV, 121, 1896, p. 3.

Loc. Vincentown, New Jersey.

Cistella plicatilis Clark. Upper Cretaceous.

Cistella plicatilis Clark, Johns Hopkins Univ. Circ., XV, 121, 1896, p. 3.

Loc. Vincentown, New Jersey.

CLEIOTHYRIS King.

Genotype Atrypa pectinifera J. de C. Sowerby=Spirifer roissyi L'Éveillé=Athyris roissyi of authors.

Cleiothyris King (non Phillips), Mon. Permian Fossils, Pal. Soc., 1850, p. 137.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 90;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 779.

Cleiothyris clintonensis (Swallow). Kaskaskia (L. Carb.).

Spirigera clintonensis Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 89.

Loc. Chester, Illinois; St. Genevieve and Cooper counties, Missouri.

Obs. Compare with C. roissyi. Regarded by Keyes as a synonym for Seminula subquadrata. However, this species does not appear to be a Seminula.

Cleiothyris crassicardinalis (White). Kinderhook (L. Carb.).

Athyris crassicardinalis White, Jour. Boston Soc. Nat. Hist., VII, 1860, p. 229.

Loc. Burlington, Iowa.

Cleiothyris hirsuta Hall. St. Louis and Kaskaskia (L. Carb.).

Spirigera (Athyris) hirsuta Hall, Trans. Albany Institute, IV, 1858, p. 8.

Athyris hirsuta Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 49, pl. 6, figs. 18–21.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 328, pl. 29, figs. 18–21.

Digitized by Google

Cleiothyris hirsuta Hall—Continued.

Cliothyris hirsuta Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 46, figs. 25–28.

Loc. Spergen Hill, Indiana; Alton and Chester, Illinois; Princeton, Kentucky; Montana.

Cleiothyris missouriensis (Swallow). Upper Carboniferous.

Spirigera missouriensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 650.

Loc. Montgomery and Chariton counties, Missouri.

Cleiothyris obmaxima (McChesney). Keokuk (L. Carb.).

Athyris obmaxima McChesney, Descriptions New Pal. Foss., 1861, p. 80.

?Spirigera obmaxima White, Wheeler's Expl. Survey west 100 Merid., IV, 1875, p. 92, pl. 5, fig. 12.

Loc. Nauvoo and Warsaw, Illinois; Keokuk, Iowa; Mountain Spring, Nevada; Ophir City, Utah.

Obs. The specimen figured by White may be Athyris incrassata Hall.

Cleiothyris obvia (McChesney). Kaskaskia (L. Carb).

Athyris obvia McChesney, Descriptions New Pal. Foss., 1861, p. 81.

Loc. Kaskaskia, Illinois.

Obs. Probably a synonym for C. roissyi.

Cleiothyris orbicularis (McChesney). Upper Carboniferous.

Athyris orbicularis McChesney, Descriptions New Pal. Foss., 1860, p. 47.

Loc. "Extensively distributed in the Western States."

Obs. Specimens of this species in the United States National Museum donated by Professor Worthen show it to be a Cleiothyris.

Cleiothyris reflexa (Swallow). Warsaw (L. Carb.).

Spirigera reflexa Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 88.

Loc. Barretts Station, St. Louis County, Missouri.

Obs. Should be compared with C. roissyi. Regarded by Keyes as a synonym for Seminula trinuclea. Swallow's species, however, does not appear to be a Seminula.

Cleiothyris roissyi (L'Éveillé). Keokuk-Kaskaskia (L. Carb.).

Spirifer de roissyi L'Éveillé, Mémoires Soc. Géol. de France, II, 1835, p. 39, pl. 2, figs. 18–20.

Terebratula royssii Marcou, Geol. North America, 1858, p. 51, pl. 6, fig. 10.

Athyris sublamellosa Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 702, pl. 27, fig. 1.—Derby, Bull. Cornell Univ., I, 1874, p. 10, pl. 2, figs. 9–12; pl. 3, figs. 15–21, 29; pl. 6, fig. 16; pl. 9, figs. 5, 6.

Athyris parvirostris Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 451.

Spirigera americana Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 89.

Spirigera pectinifera Swallow (non Sowerby), Ibidem, 1863, p. 88.

Athyris planosulcata Geinitz (non Phillips), Carbon u. Dyas in Nebraska, 1866, p. 42.—Meek and Worthen, Geol. Survey Illinois, II, 1866, p. 254, pl. 18, fig. 8.

Spirigera planosulcata? White, Wheeler's Rep. Geogr. Geol. Expl. Survey west 100 Merid., IV, 1875, p. 143, pl. 10, fig. 5.

Athyris planosulcata? Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 257, pl. 4, figs. 10, 11.

?Athyris roissyi Meek, Ibidem, 1877, p. 82, pl. 9, fig. 3.

Athyris hirsuta Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 222, pl. 18, fig. 5.

Cliothyris roysii Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 91, pl. 46, figs. 23, 24; pl. 84, fig. 32.

Digitized by Google

Cleiothyris roissyi (L'Éveillé)—Continued.

Cliothyris sublamellosa Hall and Clarke, Ibidem, 1893, p. 91.

Loc. Europe; Mississippi Valley; White Pine and Eureka districts, Nevada; Salt Lake City, etc., Utah; Lake Valley mining district, etc., New Mexico; Lake County, Colorado; Guatemala; Bomjardin and Itaituba, Brazil.

Obs. American specimens usually referred to this species are constantly smaller and are often without sinus or fold. If these differences are regarded as of sufficient importance to distinguish American specimens from typical C. roissyi then this species will be known as C. sublamellosa Hall. Of Spirigera americana Swallow, authentic specimens have been seen by the writer in Professor Hall's collection. These are identical with Athyris sublamellosa.

Meek's Athyris roissyi (1877) will probably prove to be a new species of Seminula.

See C. clintonensis, C. reflexa Swallow, and C. obvia McChesney.

Cleiothyris squamosa (Worthen). St. Louis (L. Carb.).

Athyris squamosa Worthen, Bull. Illinois State Mus. Nat. Hist., 2, 1884, p. 24;—Geol. Survey Illinois, VIII, 1890, p. 103, pl. 11, fig. 2.

Loc. Monroe County, Illinois.

CLINTONELLA Hall and Clarke.

Genotype C. vagabunda Hall and Clarke.

Clintonella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 159;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 814.

Clintonella vagabunda Hall and Clarke. Clinton (Sil.).

Clintonella vagabunda Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 160, pl. 52, figs. 1–11.

Loc. ?Orleans County, New York.

CLITAMBONITES Pander. Genotype Pronites adscendens Pander.

Klitambonites Pander, Beitrage zur Geognosie des Russischen Reiches, 1830, p. 70, pl. 3, fig. 14; pl. 28, figs. 16, 17.

Clitambonites Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1289, fig. 1059.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 233.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 377.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 274.

Clitambonites adscendens (? Pander). Ordovician.

Orthisina adscendens (Pander) Kayser, Paleontographica, Suppl., III, 1876, p. 20, pl. 2, figs. 9–11.

Loc. Europe; Juan Pobre and Laja, Cordillere Sán Juan, Argentine Republic.

Obs. This identification is probably erroneous.

Clitambonites(?) borealis (Castelnau).

"Magnesian limestone"=?Galena (Ord.).

Terebratula borealis Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 40, pl. 14, fig. 14.

Terebratula turpis de Verneuil, Ibidem, 1843, p. 40, footnote.

Loc. "Magnesian limestone of Green Bay, Wisconsin."

Obs. The figure is not satisfactory. The species seems to be related to C. diversus Shaler.

Clitambonites diversus (Shaler). Trenton-Lorraine (Ord.).

Orthisina diversa Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 67.

Orthisina veneuili Billings (non Eichwald), Catalogue Sil. Foss. Anticosti, 1866, pp. 43, 74.

Hemipronites americanus Whitfield, Ann. Rep. Geol. Survey Wisconsin, 1877, p. 72;—Geol. Wisconsin, IV, 1882, p. 243, pl. 10, figs. 15–17.

Digitized by Google

Clitambonites diversus (Shaler)—Continued.

Streptorhynchus americanus Miller, N. American Geol. Pal., 1889, p. 378.

Clitambonites americanus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 239, pl. 15A, figs. 1–8.

Clitambonites diversa Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 378, pl. 30, figs. 11–17.—Whiteaves, Pal. Fos., III, Pt. III, 1897, p. 166.

Loc. Anticosti; Cannon Falls, Kenyon, etc., Minnesota; Oshkosh, Wisconsin; Ottawa and Lake Winnipeg, Canada.

Obs. See C. borealis.

Clitambonites diversus altissimus Winchell and Schuchert. Trenton (Ord.).

Clitambonites americanus var. Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15A, figs. 7, 8.

Clitambonites diversa var. altissima Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 381, pl. 30, figs. 18, 19.

Loc. Near Cannon Falls, Minnesota.

Clitambonites (?) johannensis Matthew. Upper Cambrian.

Orthisina johannensis Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 49, pl. 12, figs. 13a–13c.

Loc. Near St. John, New Brunswick.

Clitambonites planus retroflexus (de Verneuil). Lower Ordovician.

Gonambonites plana var. retroflexa de Verneuil, Beitrage zur Geognosie des Russischen Reiches, 1830, p. 77, pl. 25, figs. 1, 2.

Clitambonites (Gonambonites) plana var. retroflexa Matthew, Trans. Roy. Soc. Canada, 2d ser., I, 1896, p. 266, pl. 2, figs. 1a–1c.

Loc. Mc. Feei, Cape Breton, Nova Scotia.

CLORINDA Barrande. Genotype C. armata Barrande.

Clorinda Barrande, Système Silurien Bohème, V, 1879.

Barrandella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 241, 243;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 844.

Clorinda arcuosa (McChesney). Niagara (Sil.).

Pentamerus arcuosus McChesney, Descriptions New Pal. Foss., 1861, p. 87.

Loc. Milwaukee, Wisconsin.

Clorinda areyi (Hall and Clarke). Clinton (Sil.).

Barrandella areyi Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. 242, 368, pl. 71, figs. 14–16.

Loc. Rochester, New York.

Clorinda barrandei (Billings). Anticosti (Sil.).

Pentamerus barrandi Billings, Geol. Survey Canada; Rep. Progress for 1856, 1857, p. 296;—Geol. Canada, 1863, p. 316, fig. 327.

Barrandella barrandii Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 243, fig. 174; pl. 71, figs. 17–20.

Loc. Anticosti.

Clorinda fornicata (Hall). Clinton and Niagara (Sil.).

Pentamerus fornicatus Hall, Pal. New York, II, 1852, p. 81, pl. 24, fig. 7.

Pentamerus fornicatus var. Hall, Descrip. n. sp. Fossils, Waldron, Indiana, 1879, p. 16;—Eleventh Rep. State Geol. Indiana, 1882, p. 299, pl. 27, fig. 15;—Trans. Albany Institute, X, 1883, p. 72.

Barrandella fornicata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 243, pl. 70, figs. 11–13.

Loc. Lockport, New York; Waldron, Indiana; Wisconsin.

Digitized by Google

Clorinda ventricosa (Hall). Niagara (Sil.).

Pentamerus ventricosa Hall, Geol. Survey Wisconsin; Rep. Progress, 1860, p. 2.—Whitfield, Geol. Wisconsin, IV, 1882, p. 291, pl. 17, figs. 11–13.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Survey, 1889, p. 64, pl. 33, figs. 12–14.

Pentamerus chicagoensis Winchell and Marcy, Mem. Boston Soc. Nat. Hist., I, 1865, p. 94, pl. 2, fig. 11.—Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1868, p. 392.

Pentamerus (Pentamerella?) ventricosa Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1868, p. 374, pl. 13, figs. 18–21.

Pentamerus (Pentamerella) ventricosus Hall and Whitfield, Pal. Ohio, II, 1875, p. 138, pl. 7, figs. 7, 8.

Barrandella ventricosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 243, pl. 71, figs. 4–10; pl. 84, fig. 46.

Loc. Waukesha, Wisconsin; Bridgeport, Illinois; Louisville, Kentucky; Ohio.

Cœlospira Hall=Anoplotheca.

Cœlospira concava Hall 1867 (not 1863)=Anoplotheca camilla.

Cœlospira disparilis Hall=Atrypina disparilis.

CONCHIDIUM Linné. Genotype C. biloculare Linné.

Conchidium Linné, Museum Tessinianum, 1753, p. 90;—Systema Naturæ, ed. xi, II, 1760, p. 163.—Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1311.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 231;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 842.

Helmintholitus Linné, Systema Naturæ, ed. xii, IV, 1766, p. 163.

Pentamerus Sowerby (non Pentamera Dumeril, 1806), Mineral Conchology, I, 1813, p. 73.

Gypidia Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, pp. 93, 100.

Pentamerus Billings, Canadian Jour., VI, 1861, p. 269.—Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 163;—Pal. New York, IV, 1867, pp. 369, 373.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 52.

Antirhynchonella Quenstedt, Petref. Deutschlands, Brach., 1871, p. 231.

Zdimir Barrande, Système Silurien Bohème, VI, 1881, p. 171.

Conchidium biloculare Linné. Silurian.

Conchidium biloculare Linné, Systema Naturæ, ed. xi, II, 1760, p. 163.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 233, pl. 6, figs. 11–14.

Pentamerus conchidium Emmerson, Geol. Frobischer Bay; Noursee Narr. Hall's Arctic Exped., 1879, p. 578.

Loc. Europe; Rescue Harbor, Arctic America.

Conchidium colletti (Miller). Waterlime (Sil.).

Petamerus colletti Miller, Seventeenth Rep. State Geol. Indiana, 1891, p. 77, pl. 13, figs. 5, 6.

Conchidium colletti Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 235, pl. 66, figs. 16, 17.

Loc. Kokomo, Indiana.

Obs. Compare with C. laqueatum Conrad.

Conchidium crassiplica Hall and Clarke. Niagara (Sil.).

Conchidium crassiplica Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. 235, 369, pl. 66, figs. 24, 25.

Loc. ?Near Louisville, Kentucky.

Conchidium crassiradiatum (McChesney). Niagara (Sil.).

Pentamerus crassoradius McChesney, Descriptions New Pal. Foss., 1861, p. 87.

Loc. Milwaukee, Wisconsin.

Digitized by Google

Conchidium decussatum (Whiteaves). **Silurian.**

Pentamerus decussatus Whiteaves, Canadian Record of Science, 1891, p. 295, pl. 3, figs. 3, 4.—Calvin, Bull. Lab. Nat. Hist. State Univ. Iowa, XI, 1892, p. 164, pl. 11, figs. 1–3; pl. 12, fig. 2.

Conchidium decussatum Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 235, pl. 65, figs. 1, 2; pl. 66, fig. 15.

Loc. Grand Rapids of the Saskatchewan, etc., Canada.

Conchidium exponeum Hall and Clarke. **Niagara** (Sil.).

Conchidium exponeus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 66, figs. 6–9.

Loc. Louisville, Kentucky.

Conchidium georgiæ Hall and Clarke. **Clinton** (Sil.).

Conchidium georgiæ Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 369, pl. 66, figs. 18, 19.

Loc. Trenton, Georgia.

Conchidium greenei Hall and Clarke. **Niagara** (Sil.).

Conchidium greenii Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. 235, 368, pl. 66, figs. 20–22.

Loc. Near Milwaukee, Wisconsin.

Conchidium knappi (Hall and Whitfield). **Niagara** (Sil.).

Pentamerus knappi Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 184.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 55, pl. 28, figs. 1–4.

Pentamerus? knappi Hall and Whitfield, Twenty-seventh Rep. New York State Cab. Nat. Hist., 1875, pl. 10, figs. 10–12.

Conchidium knappi Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 235, pl. 64, figs. 11–13.

Loc. Louisville, Kentucky.

Conchidium knighti (Nettelroth). **?Corniferous (Dev.).**

Pentamerus knighti Nettelroth (non Sowerby), Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 57, pl. 29, figs. 1, 2, 17.

Conchidium nettelrothi Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 234, pl. 64, figs. 14–16.

Loc. Louisville, Kentucky.

Obs. This species is very much like C. nysius and may be identical with it (Ami says that C. knighti occurs in the Upper Silurian at Arisaig, Nova Scotia).

Conchidium laqueatum (Conrad). **Niagara** (Sil.).

Pentamerus laqueatus Conrad, Proc. Acad. Nat. Sci. Philadelphia, VII, 1855, p. 441.

Pentamerus nobilis Emmons, Manual of Geol., 1860, p. 107, figure.

Conchidium laqueatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 232, fig. 168; p. 234, pl. 65, figs. 3–9.

Loc. Delphi, Indiana.

Conchidium littoni Hall. **Niagara** (Sil.).

Pentamerus littoni Hall, Pal. New York, III, 1859, p. 262.—Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 186;—Twenty-seventh Rep. Ibidem, 1875, pl. 10, figs. 8, 9.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 58, pl. 27, figs. 12, 13.

Conchidium littoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 64, figs. 9, 10.

Loc. Hardin County, Tennessee; Louisville, Kentucky.

Digitized by Google

Conchidium multicostatum Hall. Niagara (Sil.).

Pentamerus multicostatus Hall, Geol. Survey Wisconsin; Rep. Progress, 1860, p. 1;—Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 373, pl. 13, figs. 22–24.

Conchidium multicostatum Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 64, fig. 6; pl. 66, fig. 10.

Loc. Wauwatosa and Waukesha, Wisconsin.

Conchidium nettelrothi Hall and Clarke=C. knighti.

Conchidium nysius (Hall and Whitfield). Niagara (Sil.).

Pentamerus nysius var. crassicosta Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 184;—Twenty-seventh Rep. Ibidem, 1875, pl. 10, figs, 4–7.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 60, pl. 28, figs. 5–8.

Pentamerus nysius var. tenuicostatus Nettelroth, Ibidem, 1889, p. 60.

Conchidium nysius Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 235, pl. 64, figs. 1, 8, 27.

Loc. Louisville, Kentucky.

Obs. See C. tenuicostatum.

Conchidium obsoletum Hall and Clarke. Niagara (Sil.).

Conchidium obsoletum Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 67, figs. 8, 9.

Loc. Genoa, Ottawa County, Ohio.

Conchidium occidentale Hall. Guelph (Sil.).

Pentamerus occidentalis Hall, Pal. New York, II, 1852, p. 341, pl. 79, figs. 1, 2.—Billings, Geol. Canada, 1863, p. 337, fig. 341.—Nicholson, Pal. Prov. Ontario, 1875, p. 67, fig. 35.—Whitfield, Geol. Wisconsin, IV, 1882, p. 314, pl. 17, fig. 10; pl. 23, figs. 1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 239.

Conchidium(?) occidentalis Hall and Clarke, Ibidem, 1895, pl. 67, figs. 1–5.

Loc. Gault and Guelph, Ontario; Point St. Vital, Lake Huron; Williamstown, Wisconsin.

Conchidium(?) salinense (Swallow). "Base of Chemung" (Dev.).

Pentamerus salinensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 652.—Keyes, Geol. Survey Missouri, V, 1895, p. 104.

Loc. Moniteau County, Missouri.

Obs. The geological horizon is probably Corniferous or Hamilton.

Conchidium scoparium Hall and Clarke. Guelph (Sil.).

Conchidium scoparium Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 67, figs. 6, 7.

Loc. Durham, Ontario.

Conchidium tenuicostatum (Hall and Whitfield). Niagara (Sil.).

Pentamerus nysius var. tenuicosta Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 184;—Twenty-seventh Rep. Ibidem, 1875, pl. 10, figs. 1–3.

Pentamerus complanatus Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 53, pl. 27, figs. 14–16.

Conchidium tenuicostatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 235, pl. 64, figs. 3–5.

Loc. Louisville, Kentucky.

Obs. P. nysius is described as consisting of two varieties. If these varieties are species, as pointed out by Nettelroth, then P. nysius will be based upon and supplant variety crassicosta, while variety tenuicosta must be elevated to specific rank. P. complanatus Nettelroth, therefore, becomes a synonym for C. tenuicostatum, as both are established upon the same specimens.

Digitized by Google

Conchidium unguiforme (Ulrich). Niagara (Sil.).

Gypidia unguiformis Ulrich, Contrib. American Pal., 1886, p. 28, pl. 3, fig. 2.

Gypidula unguiformis Miller, N. American Geol. Pal., 1889, p. 346.

Conchidium unguiformis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 235, pl. 66, figs. 1–4.

Loc. Louisville, Kentucky.

CONOTRETA Walcott. Genotype C. rusti Walcott.

Conotreta Walcott, Proc. U. S. Nat. Mus., XII, 1890, p. 365 (extract 1889).—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 104, 167;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 250.

Conotreta rusti Walcott Trenton (Ord.).

Conotreta rusti Walcott, Proc. U. S. Nat. Mus., XII, 1890, p. 365, figs. 1–4 (extract 1889).—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 104, pl. 4K, figs. 16–21.

Loc. Trenton Falls, New York; Covington, Kentucky.

Conradia Hall and Clarke (non Adams)=Dinobolus.

CRANÆNA Hall and Clarke. Genotype Terebratula romingeri Hall.

Cranæna Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 297;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 865.

Cranæna iowensis (Calvin). Middle Devonian.

Terebratula (Cryptonella) iowensis Calvin, Bull. Lab. Nat. Hist. Univ. Iowa, I, 1890, p. 174, pl 3, fig. 4.

Cranæna iowensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 297, pl. 80, figs. 36–39; pl. 83, fig. 40.

Loc. Fayette, Iowa; Fulton, Missouri.

Cranæna romingeri Hall. Hamilton (Dev.).

Terebratula romingeri Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 48, figs. 22, 23;—Pal. New York, IV, 1867, p. 389, pl. 60, figs. 17–25, 66, 67.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 155, pl. 16, figs. 20–22.

Cranæna romingeri Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 297, fig. 215; pl. 80, figs. 13–19.

Loc. Thunder Bay, Michigan; Waterloo, Iowa; York and Hamburg, New York; Clarke County, Indiana.

CRANIA Retzius. Genotype Anomia craniolaris Linné.

Crania Retzius, Schrift. Ges. Naturf. Freunde, Berlin, II, 1781, p. 72.—Dall, Bull. Mus. Comp. Zool., III, 1871, p. 27;—Bull. U. S. Nat. Mus., 8, 1877, p. 21.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 31.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 145, 169.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 372.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 260.

Crania acadiensis Hall. Arisaig (Sil.).

Crania acadiensis Hall, Canadian Nat. Geol., V, 1860, p. 144, fig 1.—Dawson, Acadian Geol., 3d ed., 1878, p. 595, fig. 198.

Loc. East River, Nova Scotia.

Crania agaricina Hall and Clarke. Lower Helderberg (Dev.).

Crania agaricina Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 180, pl. 4H, fig. 2.

Loc. Albany County, New York; Decatur County, Tennessee.

Crania albersi Miller and Faber. Utica (Ord.).

Crania albersi Miller and Faber, Jour. Cincinnati Soc. Nat. Hist., XVII, 1894, p. 154, pl. 8, figs. 17–19.

Loc. Cincinnati, Ohio.

Digitized by Google

Crania alternata James=C. scabiosa.

Crania anna Spencer. Niagara (Sil.).

Crania anna Spencer, Bull. Univ. Missouri, I, 1884, p. 57;—Trans. St. Louis Acad. Sci., IV, 1886, p. 607, pl. 8, fig. 4.

Loc. Hamilton, Ontario.

Crania asperula James=C. scabiosa.

Crania aurora Hall. Schoharie Grit (Dev.).

Crania aurora Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 30;—Pal. New York, IV, 1867, p. 27, pl. 5, fig. 12.

Loc. Knox, Albany County, New York.

Crania bella Billings. No. 5 Gaspé Series (?Dev.).

Crania bella Billings, Pal. Fossils, II, 1874, p. 15, fig. 5.

Loc. Cape Bon Ami, Gaspé, Canada.

Crania blairi Miller=C. rowleyi.

Crania bordeni Hall and Whitfield=C. sheldoni.

Crania carbonaria Whitfield=C. modesta.

Crania centralis Hall. Portage (Dev.).

Crania centralis Hall, Pal. New York, V, Pt. II, 1879, pl. 88, fig. 2.

Loc. Watkins, New York.

Crania chesterensis Miller and Gurley. Kaskaskia (L. Carb.).

Crania chesterensis Miller and Gurley, Bull. Illinois State Mus. Nat. Hist., 12, 1897, p. 47, pl. 3, figs. 24–26.

Loc. Chester, Illinois.

Crania(?) columbiana Walcott. Middle Cambrian.

Crania? columbiana Walcott, Proc. U. S. Nat. Mus., XI, 1888, p. 441.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 150.

Loc. Mount Stephan, British Columbia.

Obs. Probably a species of Acrotreta.

Crania costata James=C. scabiosa.

Crania crenistriata Hall. Corniferous and Hamilton (Dev.).

Crania crenistria Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 78, fig. 6, on p. 76;—Pal. New York, IV, 1867, p. 28, pl. 3, figs. 13–16.—Hall and Clarke, Ibidem, VIII, Pt. I, 1892, pl. 4H, figs. 6–12.

Loc. Alexander, etc., New York; Columbus, Ohio; Louisville, Kentucky; Alpena, Michigan.

Obs. See C. sheldoni White.

Crania(?) deformata (Hall). Chazy (Ord.).

Orbicula? deformata Hall, Pal. New York, I, 1847, p. 23, pl. 4 bis, fig. 10.

Crania? deformata Miller, N. American Geol. Pal., 1889, p. 341.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 150.

Loc. Chazy, New York.

Obs. This species is not well established and had better be dropped since the type specimen does not preserve the generic or specific characters.

Crania dentata Ringueberg. Niagara (Sil.).

Crania dentata Ringueberg, Bull. Buffalo Soc. Nat. Sci., V, 1886, p. 16, pl. 2, fig. 6.

Loc. Lockport, New York.

?Crania dubia Foerste. Clinton (Sil.).

?Crania dubia Foerste, Geol. Ohio, VII, 1895, p. 565, pl. 37, fig. 17.

Loc. Dayton, Ohio.

Obs. May not be a brachiopod.

Digitized by Google

Crania dyeri Miller. Utica (Ord.).

Crania dyeri Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 13, fig. 3.

Loc. Cincinnati, Ohio.

Crania famelica Hall and Whitfield. Hamilton (Dev.).

Crania famelica Hall and Whitfield, Descriptions n. sp. Fossils, 1872, p. 17, pl. 11, figs. 6, 7;—Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 236, pl. 11, figs. 6, 7.

Loc. Cerro Gordo, Iowa; Callaway County, Missouri.

Obs. Compare with Craniella hamiltoniæ Hall.

Crania favincola Hall and Clarke. Middle Devonian.

Crania favincola Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 180, pl. 4H, fig. 33.

Loc. Crab Orchard, Kentucky.

Crania gracilis Ringueberg. Niagara (Sil.).

Crania gracilis Ringueberg, Bull. Buffalo Soc. Nat. Sci. V, 1886, p. 17, pl. 2, fig. 7.

Crania pannosa Ringueberg, Ibidem, 1886, p. 17, pl. 2, fig. 8.

Loc. Lockport, New York.

Obs. Species of Crania are very variable in shape, and since both forms are attached to one Orthoceras, it is probable that but a single species is here represented.

Crania granosa Hall and Clarke. Hamilton (Dev.).

Crania granosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 180, pl. 4H, figs. 19, 20.

Loc. Centerfield, New York.

Crania granulosa N. H. Winchell. Trenton (Ord.).

Crania granulosa N. H. Winchell, Eighth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1880, p. 63.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 373, pl. 29, figs. 34, 35.

Loc. Minneapolis, Minnesota.

Crania gregaria Hall=Craniella hamiltoniæ.

Crania greenei Miller. Upper Helderberg (Dev.).

Crania greenii Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 310, pl. 9, fig. 7.

Loc. Falls of Ohio.

Obs. Probably the same as Craniella hamiltoniæ.

Crania halli Sardeson=Craniella ulrichi.

Crania hamiltoniæ Hall=Craniella hamiltoniæ.

Crania lælia Hall. Utica and Lorraine (Ord.).

Crania lælia Hall, Descriptions n. sp. Crinoidea and other Fossils, 1866, p. 13;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 220, pl. 7, fig. 16.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 12.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 75, pl. 1, fig. 16.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, fig. 1.

Loc. Cincinnati and Oxford, Ohio; Richmond, Indiana.

Crania lævis Keyes. Chouteau (L. Carb.).

Crania lævis Keyes, Geol. Survey Missouri, V, 1895, p. 40.

Loc. Louisiana, Missouri.

Crania leoni Hall. Portage and Chemung (Dev.).

Crania leoni Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 78, figs. 7, 8 on p. 76;—Pal. New York, IV, 1867, p. 30, pl. 3, figs. 27-30, (?25, 26).—Hall and Clarke, Ibidem, VIII, Pt. I, 1892, pl. 4H, figs. 34, 35.

Loc. Leon, New York. Portage of Ontario County, New York (Clarke).

Digitized by Google

Crania modesta White and St. John. Upper Carboniferous.

Crania modesta White and St. John, Trans. Chicago Acad. Sci., I, 1868, p. 118.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 121, pl. 35, fig. 9; pl. 36, fig. 5.

Crania carbonaria Whitfield, Annals New York Acad. Sci., II, 1882, p. 229;—Ibidem, V, 1891, p. 599, pl. 15, figs. 11, 12;—Geol. Ohio, VII, 1895, p. 484, pl. 11, figs. 11, 12.

Loc. Fremont County, Iowa; Vermilion and Sullivan counties, Indiana; Carbon Hill, Ohio; Manhattan, Kansas.

Crania multipunctata Miller=C. scabiosa.

Crania pannosa Ringueberg=C. gracilis.

Crania parallela Ulrich=C. scabiosa.

Crania percarinata Ulrich=C. scabiosa.

Crania(?) permiana Shumard. Upper Carboniferous.

Crania permiana Shumard, Trans. St. Louis Acad. Sci., I, 1859, p. 395.

Loc. Guadalupe Mountains, New Mexico.

Obs. Probably not a Crania.

Crania pulchella Hall and Clarke. Lower Helderberg (Dev.).

Crania pulchella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 180, pl. 4H, fig. 3.

Loc. Albany County, New York.

Crania radicans A. Winchell=Strophalosia radicans.

Crania reposita White. Burlington (L. Carb.).

Crania reposita White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 30.

Loc. Burlington, Iowa.

Crania reticularis Miller=Trematis reticularis.

Crania(?) reversa Sardeson. St. Peter (Ord.).

Crania(?) reversa Sardeson, Bull. Minnesota Acad. Nat. Sci., IV, 1896, p. 77, pl. 3, figs. 6, 7.

Loc. St. Paul, Minnesota.

Crania rowleyi Gurley. Chouteau (L. Carb.).

Crania rowleyi Gurley, New Carb. Fossils, 1, 1883, p. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, fig. 13.

Crania blairi Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 310, pl. 9, figs. 5, 6.

Loc. Pike County and Sedalia, Missouri.

Crania scabiosa Hall. Utica and Lorraine (Ord.).

Crania scabiosa Hall, Descriptions n. sp. Crinoidea and other Foss., 1866, p. 13;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 220, pl. 7, fig. 15.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 74, pl. 1, fig. 17.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 12.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 148, pl. 4H, figs. 23–28, 30, 31.

Crania multipunctata Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 13, fig. 4.

Crania percarinata Ulrich, Jour. Cincinnati Soc. Nat. Hist., I, 1878, p. 98, pl. 4, fig. 12.

Crania parallela Ulrich, Ibidem, 1878, p. 98, pl. 4, fig. 13.

Crania asperula James, The Palæontologist, 3, 1879, p. 22.

Crania costata James, Ibidem, 1879, p. 22.

Crania alternata James, Ibidem, 1879, p. 23.

Loc. Cincinnati, etc., Ohio; Indiana; Illinois; Wisconsin.

Obs. The shells of Crania are adapted to the objects upon which they are cemented.

Digitized by Google

Crania scabiosa Hall—Continued.

C. scabiosa has been found growing on Rafinesquina, Strophomena, Rhynchonella, Pleurotomaria, and Monticulipora. In nearly all cases this species partakes more or less of the ornamentation of its host. The variation pointed out by authors is accidental and has no specific value.

Crania setifera Hall. Niagara (Sil.).

Crania setifera Hall, Trans. Albany Institute, IV, 1863, p. 209 (non Hall, 1866);—Twenty-eighth Rep. New York State Mus. Nat. Hist., Doc. ed., 1876, pl. 21, figs. 8–10;—Ibidem, 1879, p. 148, pl. 21, figs. 8–10;—Eleventh Rep. State Geol. Indiana, 1882, p. 283, pl. 21, figs. 8–10.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, fig. 18.

Loc. Waldron, Indiana.

Crania setigera Hall. Trenton and Lorraine (Ord.).

Crania setigera Hall, Descriptions n. sp. Crinoidea and other Fossils, 1866, p. 12;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 220, pl. 7, fig. 15.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, figs. 14–16.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 372, pl. 29, figs. 32, 33.

Loc. Mineral Point and Beloit, Wisconsin; Decorah, Iowa; Minneapolis, Cannon Falls, etc., Minnesota; Wilmington, Illinois.

Crania sheldoni White. Hamilton (Dev.).

Crania sheldoni White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 29.

Crania bordeni Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 187;—Twenty-seventh Rep. Ibidem, 1875, pl. 9, figs. 36, 37.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 32, pl. 2, fig. 14.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, figs. 4, 5.

Loc. New Buffalo and Iowa City, Iowa; Falls of Ohio.

Obs. This species may not be distinct from C. crenistria.

Crania siluriana Hall. Niagara (Sil.).

Crania siluriana Hall, Trans. Albany Institute, IV, 1863, p. 208;—Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 148, pl. 21, figs. 3–7;—Eleventh Rep. State Geol. Indiana, 1882, p. 282, pl. 21, figs. 3–7.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 13, pl. 1, figs. 1, 2.

Loc. Waldron, Indiana.

Crania socialis Ulrich. Utica (Ord.).

Crania socialis Ulrich, Jour. Cincinnati Soc. Nat. Hist., I, 1878, p. 98, pl. 4, fig. 14.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, fig. 29.

Loc. Cincinnati, Ohio.

Crania spinigera Hall. Niagara (Sil.).

Crania spinigera Hall, Descriptions n. sp. Foss. Waldron, Indiana, 1879, p. 13;—Eleventh Rep. State Geol. Indiana, 1882, p. 283, pl. 27, fig. 1;—Trans. Albany Institute, X, 1883, p. 69.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, fig. 17.

Loc. Waldron, Indiana.

Crania trentonensis Hall. Trenton (Ord.).

Crania trentonensis Hall, Descriptions n. sp. Crinoidea and other Fossils, 1866, p. 12;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 219, pl. 7, figs. 11, 12.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4H, figs. 21, 22.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 374, pl. 29, figs. 36, 37.

Loc. Middleville, New York; Cannon Falls, Minnesota; Janesville, Wisconsin; Dixon, Illinois.

Digitized by Google

CRANIELLA Œhlert. Genotype C. meduanensis Œhlert.

Craniella Œhlert, Bull. Soc. Études Scientif. d'Angers, 1888, p. 37.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 153, 170.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 374.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 262.

Craniella(?) clintonensis Foerste. Clinton (Sil.).

Craniella? clintonensis Foerste, Geol. Ohio, VII, 1895, p. 565, pl. 37, figs. 3a, 3b.

Loc. Todds Fork, Ohio.

Craniella hamiltoniæ Hall. Hamilton (Dev.).

Crania hamiltoniæ Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 77, figs. 4, 5, on p. 76;—Pal. New York, IV, 1867, p. 27, pl. 3, figs. 17–23.—Whiteaves, Cont. Canadian Pal., I, 1891, p. 214.

?Crania hamiltoniæ? Herrick, Bull. Denison Univ., III, 1888, p. 31, pl. 12, fig. 10.

Crania gregaria Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 31;—Pal. New York, IV, 1867, p. 29, pl. 3, fig. 24.

Craniella hamiltoniæ Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 148, 153, pl. 41, figs. 3–16.

Loc. Cazenovia, Hamilton, etc., New York; Hay and Athabasca rivers, Canada. (Waverly group, Moote Run, Licking County, Ohio, according to Herrick.)

Obs. See Crania greenei Miller.

Craniella(?) ulrichi Hall and Clarke. Trenton (Ord.).

Craniella ulrichi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 153, 181, pl. 4, figs. 1, 2.

Crania halli Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 328, pl. 4, figs. 8–10.

Craniella? ulrichi Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 375, pl. 29, figs. 38, 39.

Loc. Minneapolis, St. Paul, and Fountain, Minnesota.

Craniops Hall=Pholidops.

CRYPTACANTHIA White and St. John.

Genotype Waldheimia? compacta White and St. John.

Cryptacanthia White and St. John, Trans. Chicago Acad. Sci., I, 1868, p. 119.—Dall, American Jour. Conch., VI, 1870, p. 114.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 300;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 867.

Cryptacanthia compacta White and St. John. Upper Carboniferous.

Waldheimia? (Cryptacanthia) compacta White and St. John, Trans. Chicago Acad. Sci., I, 1868, p. 119, fig. 3.

Cryptacanthia compacta Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 301, fig. 225.

Loc. Madison County, Missouri.

CRYPTONELLA Hall, 1867. Genotype Terebratula rectirostra Hall.

?Cryptonella Hall, Fourteenth Rep. New York State Cab. Nat. Hist., 1861, pp. 101, 102;—Fifteenth Rep. Ibidem, 1862, p. 160, pl. 3, figs. 8, 9.—Billings, Canadian Nat. Geol., VII, 1862, p. 392.—Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 43, figs. 1–7 on p. 42;—American Jour. Sci., 2d ser., XXXV, 1863, p. 396.—Billings, Ibidem, XXXVI, 1863, p. 238.—Hall, Trans. Albany Institute, IV, 1863, pp. 132, 148.

Centronella (partim) A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 123.

Cryptonella Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 164;—Pal. New York, IV, 1867, p. 392.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 286;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 860.

Obs. This genus can not be considered as established before 1867.

Digitized by Google

Cryptonella calvini Hall and Whitfield=Dielasma calvini.

Cryptonella(?) circulus Walcott. **Devonian.**

Cryptonella? circula Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 163, pl. 15, fig. 2.

Loc. Lone Mountain, Nevada.

Obs. Additional material shows that this species attained a length of 1 inch.

Cryptonella eudora Hall and Whitfield, 1873=Dielasma calvini.

Cryptonella(?) eudora Hall. **Chemung-Waverly (Dev.-L. Carb.).**

Cryptonella (Terebratula) eudora Hall, Pal. New York, IV, 1867, p. 398, pl. 61, figs. 31–41.

Cryptonella eudora Herrick, Bull. Denison Univ., III, 1888, p. 48, pl. 5, fig. 10;—Geol. Ohio, VII, 1895, pl. 21, fig. 10.

Loc. Ithaca, New York; Licking County, Ohio.

Cryptonella(?) eximia Hall. **Lower Helderberg (Dev.).**

Cryptonella eximia Hall, Fifteenth Rep. New York State Cab. Nat. Hist., 1862, p. 160, pl. 3, figs. 6, 7;—Sixteenth Rep. Ibidem, 1863, p. 43, figs. 10, 11.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 80, figs. 11, 12.

Loc. Not given.

Cryptonella(?) inconstans (Herrick). **Waverly (L. Carb.).**

Terebratula? inconstans Herrick, Bull. Denison Univ., IV, 1888, p. 24, pl. 3. figs. 8, 9; pl. 11, fig. 18.

Cryptonella(?) inconstans Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 79, figs. 31, 32.

Terebratula inconstans Herrick, Geol. Ohio, VII, 1895, pl. 23, fig. 17.

Loc. Ashland County and Lodi, Ohio.

Cryptonella iowensis Calvin=Cranæna iowaensis.

Cryptonella iphis Hall. **Corniferous (Dev.).**

Cryptonella iphis Hall, Pal. New York, IV, 1867, p. 396, pl. 61, figs. 26–28.

Loc. Cayuga, Ontario.

Cryptonella lens Hall. **Corniferous (Dev.).**

Terebratula lens Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 89;—Pal. New York, IV, 1867, p. 386, pl. 60, figs. 1–4.

Cryptonella lens Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 199.

Loc. Clarence Hollow, New York; Falls of Ohio.

Cryptonella lincklæni Hall=Eunella lincklæni.

Cryptonella ovalis Miller. **Hamilton (Dev.).**

Cryptonella ovalis Miller, Seventeenth Rep. State Geol. Indiana, 1891, p. 76, pl. 13, figs. 1, 2.

Loc. Bunker Hill, Indiana.

Cryptonella pinonensis Walcott. **Upper Devonian.**

Cryptonella pinonensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 163, pl. 4, fig. 4.

Loc. Pinon Range, Nevada.

Cryptonella planirostris Hall. **Marcellus, Hamilton (Dev.).**

Terebratula planirostra Hall, Thirteenth Rep. New York State Cab. Nat. Hist.. 1860, p. 89.

Cryptonella planirostra Hall, Fourteenth Rep. New York State Cab. Nat. Hist.. 1861, p. 101;—Sixteenth Rep. Ibidem, 1863, p. 44;—Pal. New York, IV, 1867, p. 395, pl. 61, figs. 9–27.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 287, fig. 208; pl. 80, figs. 5–10.

Loc. Seneca and Canandaigua lakes, New York.

Digitized by Google

Cryptonella rectirostris Hall. Hamilton (Dev.).

Terebratula rectirostra Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 88.

Cryptonella rectirostra Hall, Fourteenth Rep. New York State Cab. Nat. Hist., 1861, p. 101;—Sixteenth Rep. Ibidem, 1863, p. 44;—Pal. New York, IV, 1867, p. 394, pl. 61, figs. 1–8.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 286, pl. 80, figs. 1–4.

Loc. Bellona, York, Moscow, etc., New York; Falls of Ohio.

Cryptonella subelliptica Hall and Clarke. Waverly (L. Carb.).

Cryptonella subelliptica Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 81, figs. 41–43.

Loc. Sciotoville, Ohio.

CYCLORHINA Hall and Clarke. Genotype Rhynchospira nobilis Hall.

Cyclorhina Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 206;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 830.

Cyclorhina nobilis Hall. Hamilton (Dev.).

Rhynchospira nobilis Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 83.

Rhynchospira and Trematospira? nobilis Hall, Pal. New York, IV, 1867, pp. 277, 412, pl. 63, figs. 33–36.

Retzia (Trematospira) nobilis Whiteaves, Cont. Canadian Pal., I, 1889, p. 116.

Cyclorhina nobilis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 207, pl. 61, figs. 1–12.

Loc. Darien, New York; Thedford, Ontario.

CYCLOSPIRA Hall and Clarke. Genotype Orthis bisulcata Emmons.

Cyclospira Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 146.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 469.—Hall and Clarke, Thirteenth Ann. Rep. New York State Geologist, 1895, p. 808.

Cyclospira bisulcata (Emmons). Trenton (Ord.).

Orthis bisulcata Emmons, Geol. New York; Rep. Second Dist., 1842, p. 396, fig. 4.

Atrypa bisulcata Hall, Pal. New York, I, 1847, p. 139, pl. 33, fig. 3.

Genus? bisulcata Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 65.

Camarella bisulcata Miller, American Pal. Foss., 1877, p. 107.

Camarella owatonnensis Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 328, pl. 4, figs. 1–3.

Cyclospira bisulcata? Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 470, pl. 34, figs. 49–54.

Cyclospira bisulcata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 147, figs. 133–136; pl. 54, figs. 38–40;—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 180.

Loc. Adams, Jefferson County, New York; Ottawa, Canada; Cannon Falls, etc., Minnesota; Lake Winnipeg, Manitoba.

Cyclospira(?) sparsiplica Foerste. Clinton (Sil.).

Cyclospira? sparsiplica Foerste, Geol. Ohio, VII, 1895, p. 593, pl. 37A, fig. 18.

Loc. Dayton, Ohio.

Obs. May be a species of Parastrophia or a rhynchonelloid.

CYRTIA Dalman. Genotype Anomites exporrectus Wahlenberg.

Cyrtia Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, pp. 93, 97.—Billings, Canadian Jour., VI, 1861, p. 262.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 93.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 40;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 759.

Cyrtia acutirostris Shumard=Cyrtina acutirostris.

Digitized by Google

Cyrtia alta Hall. Waverly (L. Carb.).

Spirifer alta Hall, Proc. American Phil. Soc., X, 1866, p. 246;—Pal. New York, IV, 1867, p. 248, pl. 43, figs. 1–7.

Syringothyris alta Schuchert, Ninth Ann. Rep. New York State Geol., 1890, p. 35.

Cyrtia alta Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 42, pl. 26, figs. 1–5; pl. 39, figs. 37, 38.

Loc. Meadville, Pennsylvania; Bedford, Ohio.

Cyrtia biplicata Hall=Cyrtina biplicata.

Cyrtia curvilineata White=Cyrtina curvilineata.

Cyrtia cyrtiniformis (Hall and Whitfield). Chemung (Dev.).

Spirifera cyrtinaformis Hall and Whitfield, Twenty-third Rep. New York State Cab. Nat. Hist., 1872, p. 238, pl. 11, figs. 21–24;—Extract, 1872, p. 19, pl. 11, figs. 21–24.—Whiteaves, Cont. to Canadian Pal., I, 1891, p. 222.

Cyrtia cyrtiniformis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 42, pl. 25, figs. 26–32.

Loc. Rockford, Iowa; Hay River, Canada.

Obs. Compare with C. norwoodi Meek.

Cyrtia dalmani Hall=Cyrtina dalmani.

Cyrtia exporrecta (Wahlenberg). Niagara (Sil.).

Anomites exporrectus Wahlenberg, Nova Acta Regiæ Soc. Scient. Upsal, VIII, 1821, p. 64.

Spirifera (Cyrtia) trapezoidalis Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 183.

Cyrtia trapezoidalis Hall and Whitfield, Twenty-seventh Rep. Ibidem, 1875, pl. 9, figs. 19–21.

Cyrtia exporrecta Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 93, pl. 27, figs. 6–8, 20.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 42, pl. 28, figs. 1, 48, 49, 51.

Loc. Europe; Louisville, Kentucky.

Cyrtia exporrecta arrecta Hall and Whitfield=C. myrtea.

Cyrtia gigas Troost=Syringothyris gigas.

Cyrtia hamiltonensis Hall=Cyrtina hamiltonensis.

Cyrtia meta (Hall). Clinton and Niagara (Sil.).

Spirifer radiatus (pars) Hall, Pal. New York, II, 1852, p. 66, pl. 22, figs. 2a–2c, 2f.

Spirifera meta Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 372, pl. 13, figs. 12, 13.

Cyrtia radians Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 42, 362, pl. 28, figs. 4, 5, 50, 52; pl. 39, fig. 33.

Loc. Lockport and Rochester, New York; Milwaukee, Wisconsin.

Cyrtia missouriensis Swallow=Cyrtina missouriensis.

Cyrtia myrtia Billings. Anticosti and Niagara (Sil.).

Cyrtia myrtia Billings, Pal. Fossils, I, 1862, p. 165, fig. 149.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 42.

Cyrtia trapezoidalis var. arrecta Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 183.

Cyrtia exporrecta Hall and Whitfield, Twenty-seventh Rep. Ibidem, 1875, pl. 9, figs. 22, 23.

Cyrtia exporrecta var. arrecta Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 94, pl. 27, fig. 21; pl. 34, fig. 35; pl. 37, figs. 60, 61.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 28, figs. 2, 3; pl. 39, fig. 32.

Loc. Anticosti; Louisville, Kentucky.

Digitized by Google

Cyrtia norwoodi (Meek). Middle Devonian.

Spirifera norwoodi Meek, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 308.

Spirifera utahensis Meek, note appended to extra copies of the above-cited paper, 1860;—Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p. 345, pl. 1, fig. 4;—King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 39, pl. 3, fig. 1.

Loc. Buell Valley, Utah.

Obs. Compare with C. crytiniformis Hall and Whitfield.

Cyrtia occidentalis Swallow=Cyrtina occidentalis.

Cyrtia radians Hall and Clarke=C. meta.

Cyrtia rostrata Hall=Cyrtina rostrata.

Cyrtia trapezoidalis Hisinger=C. exporrecta.

Cyrtia trapezoidalis arrecta Hall and Whitfield=C. myrtia.

Cyrtia triquetra Hall=Cyrtina triquetra.

Cyrtia umbonata Hall=Cyrtina umbonata.

CYRTINA Davidson. Genotype Cyrtia heteroclita Defrance.

Cyrtina Davidson, Mon. British Carb. Brachiopoda, Pal. Soc., 1858, p. 66.—Hall, Pal. New York, IV, 1867, p. 263;—Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 251.—Herrick, Bull. Dennison Univ., IV, 1888, p. 14.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 95.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 43;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 763.

Cyrtina acutirostris (Shumard). Chouteau (L. Carb.).

Cyrtia acutirostris Shumard, Geol. Rep. Missouri, 1855, p. 204, pl. C, fig. 3.

Cyrtina acutirostris Miller, N. American Geol. Pal., 1889, p. 342.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 28, figs. 38–42, 44, 54.—Keyes Geol. Survey Missouri, V, 1895, p. 89, pl. 39, fig. 10.

Loc. Hannibal and Louisiana, Missouri.

Cyrtina affinis Billings. Oriskany (Dev.)

Cyrtina dalmani Billings, Canadian Nat. Geol., VIII, 1863, p. 37.

Cyrtina affinis Billings, Pal. Fossils, II, 1874, p. 49, pl. 3A, fig. 6.

Loc. Grand Greve, Gaspé.

Cyrtina billingsi Meek. Hamilton (Dev.).

Cyrtina billingsi Meek, Trans. Chicago Acad. Sci., I, 1868, p. 97, pl. 14, fig. 6.—Whiteaves, Cont. to Canadian Pal., I, 1891, p. 227.

Loc. Clearwater and Athabasca rivers, British America.

Cyrtina biplicata Hall. Upper Helderberg (Dev.).

Cyrtia biplicata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 165.

Cyrtina biplicata Hall, Pal. New York, IV, 1867, p. 266, pl. 27, figs. 5–10.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 28, figs. 7–10.

Loc. Albany and Schoharie counties, etc., New York; Michigan.

Cyrtina burlingtonensis Rowley. Burlington (L. Carb.).

Cyrtina burlingtonensis Rowley, American Geologist, XII, 1893, p. 308, pl. 14, figs. 15–17.

Loc. Louisiana, Missouri.

Obs. Compare with C. neogenes.

Cyrtina crassa Hall. Corniferous (Dev.).

Cyrtina crassa Hall, Pal. New York, IV, 1867, p. 267, pl. 27, figs. 11, 12.—Hall and Whitfield, Twenty-seventh Rep. New York State Cab. Nat. Hist., 1875, pl. 9, figs. 14–16.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 95, pl. 13, figs. 21–24.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 28, figs. 13–15.

Loc. Vienna, New York; Falls of Ohio.

Digitized by Google

Cyrtina(?) curupira Rathbun. Middle Devonian.

Cyrtina(?) curupira Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 242, pl. 10. figs 1, 6.

Loc. Erere, Province of Para, Brazil.

Cyrtina curvilineata White. Hamilton (Dev.).

Cyrtia curvilineata White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 25.

Cyrtina curvilineata? Hall, Pal. New York, IV, 1867, p. 270, pl. 44, figs. 53–55.

Cyrtina curvilineata Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 28, figs. 11, 12

Loc. Iowa City, Iowa.

Cyrtina dalmani Billings (non Hall)=C. affinis.

Cyrtina dalmani (Hall). Lower Helderberg (Dev.).

Cyrtia dalmani Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 64;—Pal. New York, III, 1859, p. 206, pl. 24, fig. 1.

Cyrtina dalmani Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 383, pl. 7, fig. 3.

Loc. Albany and Schoharie counties, New York; Perry County, Missouri; Decatur County, Tennessee; Dalhousie, New Brunswick.

Cyrtina davidsoni Walcott. Middle and Upper Devonian.

Cyrtina davidsoni Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 146, pl. 3, fig. 2.

Loc. White Pine district, Nevada.

Cyrtina hamiltonensis Hall. Up. Helderberg, Ham., and Port. (Dev.).

Cyrtia hamiltonensis Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 166.—Billings, Canadian Jour., VI, 1861, p. 262, figs. 80–82;—Geol. Canada, 1863, p. 384, fig. 415.

Cyrtina hamiltonensis Hall, Pal. New York, IV, 1867, p. 268, pl. 27, figs. 1–4; pl. 44, figs. 26–33, 38–52.—Meek, Trans. Chicago Acad. Sci., I, 1868, p. 99, pl. 14, figs. 5, 7, 10.—Nicholson, Pal. Prov. Ontario, 1874, p. 83.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 147.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 96, pl. 13, figs. 4–12.—Whiteaves, Cont. to Canadian Pal., I, 1891, pp. 226, 288.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 28, figs. 23–33, 43, 45, 46, 53.—Kindle, Bull. American Pal., 6, 1896, p. 35.

Cyrtina panda Meek, Trans. Chicago Acad. Sci., I, 1868, p. 100, pl. 14, fig. 8.

Loc. New York; Pennsylvania; Maryland; Cayuga and Thedford, Ontario; Louisville, Kentucky; Independence, Iowa; Eureka district, Nevada; Mackenzie and Athabasca rivers, and lakes Manitoba and Winnipegosis, British America.

Obs. C. panda is a variation of this species with a higher ventral area.

Cyrtina hamiltonensis recta Hall. Hamilton and Chemung (Dev.).

Cyrtina hamiltonensis var. recta Hall, Pal. New York, IV, 1867, p. 270, pl. 44, figs. 34–37.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 97, pl. 13, figs. 13–16.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 28, figs. 21, 22.

Loc. Allegany County, New York; Falls of Ohio.

Cyrtina lachrymosa Hall and Clarke. Waverly (L. Carb.).

Cyrtina lachrymosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. 46, 362, pl. 28, figs. 36, 37, 47.

Loc. Richfield, Ohio.

Cyrtina missouriensis (Swallow). Hamilton (Dev.).

Cyrtia missouriensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 647.

Cyrtina missouriensis Miller, N. American Geol. Pal., 1889, p. 343.

Loc. Callaway County, Missouri.

Obs. Regarded by Keyes as a synonym for C. umbonata.

Digitized by Google

Cyrtina neogenes Hall and Clarke. Burlington (L. Carb.).

Cyrtina neogenes Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 84, fig. 41.

Loc. Burlington, Iowa.

Obs. Compare with C. burlingtonensis.

Cyrtina(?) occidentalis (Swallow). Hamilton (Dev.).

Cyrtia occidentalis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 648.

Cyrtina? occidentalis Miller, N. American Geol. Pal., 1889, p. 343.

Syringothyris occidentalis Keyes, Geol. Survey Missouri, V, 1889, p. 86.

Loc. Callaway County, Missouri.

Obs. This is probably a Spirifer with a high area as in S. asperus, or it is a Cyrtia.

Cyrtina panda Meek=C. hamiltonensis.

Cyrtina pyramidalis (Hall). Niagara (Sil.).

Spirifer pyramidalis Hall, Pal. New York, II, 1852, p. 266, pl. 54, fig. 7.

Cyrtina pyramidalis Miller, N. American Geol. Pal., 1889, p. 343.

Loc. Lewiston, New York.

Cyrtina rostrata Hall. Oriskany and Corniferous (Dev.).

Cyrtia rostrata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 64;—Pal. New York, III, 1859, p. 429, pl. 96, figs. 1-6; pl. 98, fig. 8.—Billings, Canadian Jour., VI, 1861, p. 263.

Cyrtina rostrata Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 25, figs. 1-8; pl. 28, fig. 6.

Loc. Albany County, New York; Cumberland, Maryland; Cayuga, Ontario.

Cyrtina triplicata Simpson. Waverly (L. Carb.).

Cyrtina triplicata Simpson, Trans. American Phil. Soc., n. ser., XVI, 1889, p. 439, fig. 4.

Loc. Warren, Pennsylvania.

Cyrtina triquetra (Hall). Hamilton (Dev.).

Cyrtia triquetra Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 513.

Cyrtina triquetra Meek, Trans. Chicago Acad. Sci., I, 1868, p. 99.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 436, pl. 13, fig. 4.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 28, figs. 14, 35.

Loc. Rock Island, Illinois.

Cyrtina umbonata (Hall). Hamilton (Dev.).

Cyrtia umbonata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 512, pl. 5, fig. 2.

Cyrtina umbonata Miller, N. American Geol. Pal., 1889, p. 343.—Keyes, Geol. Survey Missouri, V, 1895, p. 90.

Loc. Buffalo, Iowa; Rock Island, Illinois; Callaway County, Missouri.

Obs. See C. missouriensis.

Cyrtina umbonata alpenaensis Hall and Clarke. Hamilton (Dev.).

Cyrtina umbonata var. alpenensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 362, pl. 28, figs. 16-20.

Loc. Alpena, Michigan.

DALMANELLA Hall and Clarke.

Genotype Orthis testudinaria Dalman.

Orthis (group of O. testudinaria) Hall, Bull. Geol. Soc. America, I, 1889, p. 21.

Dalmanella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 205, 223.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 439.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 170.

Digitized by Google

Dalmanella amœna N. H. Winchell. **Trenton (Ord.).**

Orthis amœna Winchell, Eighth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1880, p. 65.

Orthis (D.) amœna Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 453, pl. 33, figs. 48–50.

Loc. Spring Valley, Minnesota.

Dalmanella arcuaria Hall and Clarke. **Niagara (Sil.).**

Dalmanella arcuaria Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 224, 341, pl. 5C, figs. 20, 21.

Loc. Perry County, Tennessee.

Dalmanella bellula (Meek). **Lorraine (Ord.).**

Orthis bellula (James MS.) Meek, Pal. Ohio, I, 1873, p. 103, pl. 8, fig. 5; Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 31.

Dalmanella bellula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Loc. Cincinnati, Ohio.

Dalmanella concinna Hall. **Lower Helderberg (Dev.).**

Orthis concinna Hall, Pal. New York, III, 1859, p. 172, pl. 13, figs. 1–3.

Dalmanella concinna Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224.

Loc. Cumberland, Maryland.

Dalmanella crispata (Emmons). **Lorraine (Ord.).**

Orthis crispata Emmons, Geol. New York; Rep. Second Dist., 1842, p. 404, fig. 5.

Dalmanella crispata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Loc. Lorraine, New York.

Dalmanella devonica (Walcott). **Lower Devonian.**

Skenidium devonicum Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 116, pl. 13, fig. 4.

Loc. Eureka district, Nevada.

Obs. The type specimen has no spondylium and therefore is no Scenidium.

Dalmanella electra (Billings). **Calciferous (Ord.).**

Orthis electra Billings, Pal. Fossils, I, 1862, p. 79, fig. 72; p. 217;—Geol. Canada, 1863, p. 231, fig. 246.

Orthis electra? White, Wheeler's Rep. Geol. Geogr. Expl. west 100 Merid., IV, 1875, p. 55.

Dalmanella electra Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 223.

Loc. Point Levis and St. John, Canada; Newfoundland; House Range, Utah.

Dalmanella electra major (Matthew). **Calciferous (Ord.).**

Orthis electra var. major Matthew, Trans. Royal Soc. Canada, X, 1893, p. 100, pl. 7, fig. 3.

Loc. Near St. John, New Brunswick.

Dalmanella electra lævis (Matthew). **Calciferous (Ord.).**

Orthis electra var. lævis Matthew, Trans. Royal Soc. Canada, X, 1893, p. 100.

Loc. Near St. John, New Brunswick.

Dalmanella elegantula (Dalman). **Clinton and Niagara (Sil.).**

Orthis elegantula Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, p. 117, pl. 2, fig. 6.—Hall, Pal. New York, II, 1852, p. 252, pl. 52, fig. 3.—Billings, Canadian Nat. Geol., I, 1856, p. 136, pl. 2, fig. 5.—Roemer, Sil. Fauna west. Tennessee, 1860, p. 62, pl. 5, fig. 7.—Billings, Geol. Canada, 1863, p. 312, fig. 320.—Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 150, pl. 21, figs. 11–17;—Eleventh Rep. State Geol. Indiana, 1882, p. 285, pl. 21, figs. 11–17;—Second Ann. Rep. New York State Geol., 1883,

Digitized by Google

Dalmanella elegantula (Dalman)—Continued.

pl. 35, figs. 34–37.—Foerste, Bull. Denison Univ., I, 1885, p. 84, pl. 13, fig. 1.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 37, pl. 32, figs. 52–57.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 14, pl. 1, figs. 3–12.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 307.

Orthis canalis Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 105, fig. 6.

Orthis elegantula? var. Hall, Pal. New York, II, 1852, p. 57, pl. 20, fig. 7.

Dalmanella elegantula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224, pl. 5C, figs. 15–19.

Orthis (Dalmanella) elegantula Foerste, Geol. Ohio, VII, 1895, p. 581, pl. 25, figs. 11, 17.

Loc. Europe; New York; Ohio; Indiana; Kentucky; Tennessee; Missouri; Ontario and Nova Scotia, Canada; Collinsville, Alabama.

Dalmanella elegantula parva (Foerste). Clinton (Sil.).

Orthis elegantula var. parva Foerste, Bull. Denison Univ., I, 1885, p. 85, pl. 13, fig. 17.

Dalmanella elegantula var. parva Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Loc. Dayton, Ohio.

Dalmanella(?) evadne (Billings). Calciferous (Ord.).

Orthis evadne Billings, Pal. Fossils, I, 1862, p. 81, fig. 74; p. 79.—Whitfield, Bull. American Mus. Nat. Hist., I, 1886, p. 300, pl. 24, fig. 8.

Dalmanella? evadne Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 223, pl. 5B, figs. 25, 26.

Loc. Point Levis, Canada; Fort Cassin, Vermont.

Dalmanella hamburgensis (Walcott). Pogonip and Trenton (Ord.).

Orthis hamburgensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 73, pl. 2, fig. 5.

Orthis (Dalmanella) hamburgensis? Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 440, pl. 33, figs. 14–16.

Loc. Pogonip group, Eureka district, Nevada. In the Trenton at St. Paul, Cannon Falls, etc., Minnesota; Highbridge, Kentucky.

Dalmanella infera (Calvin). Chemung (Dev.).

Orthis infera Calvin, Bull. U. S. Geol. Survey Terr., IV, 1878, p. 728.

Dalmanella infera Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Loc. Independence, Iowa; Naples, New York.

Dalmanella lenticularis (Vanuxem). Corniferous (Dev.).

Orthis lenticularis Vanuxem (non Wahlenberg), Geol. New York; Rep. Third Dist., 1842, p. 139, fig. 4.—Hall, Pal. New York, IV, 1867, p. 35, pl. 5, figs. 1, 2.

Orthis lenticularis and O. lentiformis Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 175, fig. 4.

Orthis eboracensis Miller, N. American Geol. Pal., 1889, p. 357.

Dalmanella lenticularis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224, pl. 5C, figs. 36–41.

Loc. Leroy, Caledonia, etc., New York.

Dalmanella lepida Hall. Hamilton (Dev.).

Orthis lepidus Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 78;—Pal. New York, IV, 1867, p. 46, pl. 6, fig. 1.

Dalmanella lepida Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207,224.

Loc. Ontario County, New York.

Digitized by Google

Dalmanella macleodi (Whitfield). **Calciferous (Ord.).**

Orthis macleodi Whitfield, Bull. American Mus. Nat. Hist., II, 1889, p. 43, pl. 7, figs. 1–4.

Dalmanella macleodi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Loc. Beekmantown, New York.

Dalmanella melita (Hall and Whitfield). **Upper Cambrian.**

Leptæna melita Hall and Whitfield, King's U. S. Geol. Survey, 40th Parl., IV, 1877, p. 208, pl. 1, figs. 13, 14.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 22.

Loc. Eureka district, Nevada.

Obs. This species is related to D. evadne (Billings).

Dalmanella(?) nettoana (Rathbun). **Middle Devonian.**

Orthis nettoana Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 247, pl. 10, figs. 7, 10, 13;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 22.

Loc. Province of Para, Brazil.

Dalmanella parva (de Verneuil). **Anticosti (Sil.).**

Orthis parva (Pander) de Verneuil, Geology of Russia and the Ural Mountains, 1845, p. 188, pl. 13, fig. 3.—Billings, Cat. Sil. Foss. Anticosti, 1866, p. 41.

Loc. Europe; Anticosti.

Dalmanella perelegans Hall. **Lower Helderberg (Dev.).**

Orthis perelegans Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 44, fig. 1;—Pal. New York, III, 1859, p. 171, pl. 13, figs. 4–12;—Second Ann. Rep. New York State Geol., 1883, pl. 35, figs. 32, 33.

Dalmanella perelegans Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224, pl. 5C, figs. 34, 35.

Loc. Albany and Schoharie counties, New York; Decatur County, Tennessee.

Dalmanella planiconvexa Hall. **Lower Helderberg and Oriskany (Dev.).**

Orthis planoconvexa Hall, Pal. New York, III, 1859, p. 168, pl. 12, figs. 1–6.

Dalmanella planoconvexa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224.

Loc. Albany County, New York; Cumberland, Maryland.

Dalmanella(?) plicifera (Hall). **Chazy (Ord.).**

Leptæna plicifera Hall, Pal. New York, I, 1847, p. 19, pl. 4 bis, fig. 1.

Strophomena plicifera Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 70.

Loc. Chazy, New York.

Dalmanella pogonipensis (Hall and Whitfield). **Pogonip (Ord.).**

Orthis pogonipensis Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 232, pl. 1, figs. 9, 10.

Strophomena nemea H. and W., Ibidem, 1877, p. 233, pl. 1, fig. 15.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 71.

Loc. White Pine and Eureka districts, Nevada.

Obs. These are shells of the D. perveta group. S. nemea is based on a dorsal valve of O. pogonipensis.

Dalmanella quadrans Hall. **Lower Helderberg (Dev.).**

Orthis quadrans Hall, Pal. New York, III; Corrigenda in vol. with plates, 1861, pl. 12, figs. 9–12.

Dalmanella quadrans Hall and Clarke, Ibidem, VIII, Pt. I, 1892, p. 224.

Loc. Catskill and Schoharie, New York.

Digitized by Google

Dalmanella stonensis (Safford). Trenton (Ord.).

Orthis stonensis Safford, Geol. Tennessee, 1869, p. 286.

Dalmanella stonensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224, pl. 5C, figs. 4, 5.

Loc. Near Nashville, Tennessee.

Dalmanella subæquata (Conrad). Trenton (Ord.).

Orthis subæquata Conrad, Proc. Acad. Nat. Sci. Philadelphia, I, 1843, p. 333.—Hall, Pal. New York, I, 1847, p. 118, pl. 32, fig. 2;—Geol Wisconsin, I, 1862, p. 42, figs. 1-3, and p. 436;—Second Ann. Rep. New York State Geol., 1883, pl. 34, figs. 19-24.

Orthis minneapolis N. H. Winchell, Eighth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1880, p. 63.

Orthis perveta Hall, Second Ann. Rep. New York State Geol., 1883, pl. 34, figs. 17, 18 (?16).

Dalmanella subæquata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 194, 207, 224, pl. 5C, figs. 6-11.

Dalmanella perveta Hall and Clarke, Ibidem, 1892, p. 224, pl. 5C, figs. 13, 14.

Orthis (D.) subæquata Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 446, pl. 33, figs. 30-36.

Loc. Mineral Point, Wisconsin; Minneapolis, St. Paul, Cannon Falls, Fountain, etc., Minnesota; Decorah and McGregor, Iowa; Auburn, Lincoln County, Missouri; Montreal, Canada.

Dalmanella subæquata circularis N. H. Winchell. Trenton (Ord.).

Orthis circularis N. H. Winchell, Eighth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1880, p. 66.

Orthis (D.) subæquata var circularis Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 452, pl. 33, figs. 46, 47.

Loc. Minneapolis, Cannon Falls, etc., Minnesota; Highbridge, Kentucky; Lebanon, Tennessee.

Dalmanella subæquata conradi N. H. Winchell. Trenton (Ord.).

Orthis conradi N. H. Winchell, Eighth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1880, p. 68.

Orthis (D.) subæquata var. conradi Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 449, pl. 33, figs. 37-39.

Loc. Minneapolis, Minnesota; Decorah, Iowa; Janesville and Beloit, Wisconsin; Montreal, Canada; ?Eureka district, Nevada.

Dalmanella subæquata gibbosa (Billings). Chazy-Trenton (Ord.).

Orthis gibbosa Billings, Geol. Survey Canada; Rep. Progress for 1856, 1857, p. 296;—Canadian Nat. Geol., IV, 1859, p. 434.

Dalmanella gibbosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Orthis (D.) subæquata var. gibbosa Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 451, pl. 33, figs. 43-45.

Loc. Near Ottawa and Bellville, Canada; Minneapolis, Cannon Falls, etc., Minnesota; Decorah, Iowa; Mineral Point, Wisconsin; in the Chazy, Island of Montreal, and Pallideau Islands, Lake Huron.

Dalmanella subæquata pervetus (Conrad). Trenton (Ord.).

Orthis perveta Conrad, Proc. Acad. Nat. Sci. Philadelphia, I, 1843, p. 333.—Hall, Pal. New York, I, 1847, p. 120, pl. 32, fig. 5.—Billings, Canadian Nat. Geol., IV, 1859, p. 434, fig. 10.—Hall, Geol. Wisconsin, I, 1862, p. 42, fig. 7.—Billings, Geol. Canada, 1863, p. 130, fig. 57.

Orthis media N. H. Winchell, Eighth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1880, p. 64.

Digitized by Google

Dalmanella subæquata pervetus (Conrad)—Continued.

Orthis kassubæ N. H. Winchell, Ibidem, 1880, p. 65.

?Orthis perveta Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 72, pl. 11, fig. 3.

Dalmanella perveta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 5C, fig. 12.

Orthis (D.) subæquata var. perveta Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 450, pl. 33, figs. 40–42.

Loc. Mineral Point, Beloit, etc., Wisconsin; Minneapolis, St. Paul, Cannon Falls, etc., Minnesota; Decorah, Iowa; Dixon, Illinois; Tennessee.

Dalmanella subcarinata Hall. Lower Helderberg (Dev.).

Orthis subcarinata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 43, figs. 1, 2;—Pal. New York, III, 1859, p. 169, pl. 12, figs. 7, 8, 13–21 (not figs. 9–12 = D. quadrans).—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 373, pl. 7, fig. 6.—Whitfield, Geol. Wisconsin, IV, 1882, p. 320, pl. 25, figs. 3, 4.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 35, figs. 23–31.

?Orthis subcarinata Tscherneyschew, Fauna Untern Devon des Urals, Mém. Com. Géol., Russia, IV, 1885, p. 57, pl. 7, fig. 97.

Dalmanella subcarinata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224, pl. 5C, figs. 25–33.

Loc. Catskill, Schoharie, etc., New York; Perry and Pike counties, Missouri; Decatur County, Tennessee; Waubakee, Wisconsin; Arisaig, Nova Scotia (Ami); Russia.

Dalmanella superstes Hall and Clarke. Chemung (Dev.).

Dalmanella superstes Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224, 342, pl. 5C, figs. 44–47.

Loc. Near Howard, Steuben County, New York.

Dalmanella tenuilineata (Hall). Chemung (Dev.).

Atrypa? tenuilineata Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 271, fig. 4.

Orthis leonensis Hall, Pal. New York, IV, 1867, p. 62, pl. 8, figs. 3–8.

Dalmanella leonensis Hall and Clarke, Ibidem, VIII, Pt. I, 1892, p. 224, pl. 5C, figs. 42, 43.

Loc. Leon, Conewango, etc., New York.

Dalmanella tersa (Sardeson). Lorraine (Ord.).

Orthis tersus Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 331, pl. 5, figs. 11–13;—American Geol., XIX, 1897, p. 100, pl. 5, figs. 8–13.

Loc. Wilmington, Illinois; Nye, Wisconsin.

Dalmanella testudinaria (Dalman). Chazy-Lorraine (Ord.).

Orthis testudinaria Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, p. 115, pl. 2, fig. 4.—Conrad, Ann. Rep. Geol. Survey New York, 1839, p. 63.—Hall, Pal. New York, I, 1847, p. 117, pl. 32, fig. 1; p. 288, pl. 79, fig. 4.—Billings, Canadian Nat. Geol., I, 1856, p. 40, fig. 1.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 818, fig. 601.—Billings, Geol. Canada, 1863, p. 165, fig. 144.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 20.—Whitfield, Geol. Wisconsin, IV, 1882, p. 258, pl. 12, figs. 5–7.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 34, figs. 1–4, 6–13.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 72, pl. 11, fig. 10.—Sardeson, American Geol., XIX, 1897, p. 92.

Orthis striatula Emmons, Geol. New York; Rep. Second Dist., 1842, p. 394, fig. 3.

Orthis testudinaria? Emmons, Ibidem, 1842, p. 404, fig. 4.—White, Wheeler's Expl. Survey west 100 Merid., IV, 1875, p. 72.

Orthis disparilis Owen (non Conrad), Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 2B, fig. 23 (see specimens U. S. Nat. Mus., Cat. Invert. Foss., 17887).

Digitized by Google

Dalmanella testudinaria (Dalman)—Continued.

Dalmanella testudinaria Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 190, 206, 218, 224, pl. 5B, figs. 27–39.

Orthis rogata Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 331, pl. 5, figs. 1–4;—American Geol., XIX, 1897, p. 95, pl. 4, figs. 1–10.

Orthis (Dalmanella) testudinaria Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 441, pl. 33, figs. 17–22.—Whiteaves, Pal. Foss., III, Pt. III, 1897, pp. 177, 241.

Loc. Europe; throughout the extent of the formations in America.

Dalmanella testudinaria emacerata Hall. Utica (Ord.).

Orthis emacerata Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 121;—Fifteenth Rep. Ibidem, 1862, pl. 2, figs. 1–3.—Billings, Canadian Nat. Geol., VII, 1862, p. 393.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 24.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 34, figs. 14, 15.—Keyes, Geol. Survey Missouri, V, 1895, p. 58.—Sardeson, American Geol., XIX, 1897, p. 102, pl. 5, figs. 14, 18, 28.

Orthis cyclus James, Cincinnati Quart. Jour. Sci., I, 1874, p. 19.

Dalmanella emacerata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224, pl. 5C, figs. 1, 2.

Orthis macrior Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 330, pl. 5, figs. 5–7.

Orthis (D.) testudinaria var. emacerata Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 445, pl. 33, figs. 23, 24.

Loc. Cincinnati, Ohio; Spring Valley and Granger, Minnesota; Cape Girardeau, Missouri; St. Croix, Quebec, Canada.

Dalmanella testudinaria futilis (Sardeson). Trenton (Ord.).

Orthis futilis Sardeson, American Geol., XIX, 1897, p. 104, pl. 5, figs. 25–27.

Loc. Near Granger and Wykoff, Minnesota.

Dalmanella testudinaria ignota (Sardeson). Lorraine (Ord.).

Orthis ignota Sardeson, American Geol., XIX, 1897, p. 99, pl. 5, figs. 1–7.

Loc. Near Spring Valley, Minnesota.

Dalmanella testudinaria meeki (Miller). Lorraine (Ord.).

Orthis emacerata Meek (non Hall), Pal. Ohio, I, 1873, p. 109, pl. 8, figs. 1, 2

Orthis meeki Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 20.—Sardeson, American Geol., XIX, 1897, p. 98, pl. 4, figs. 24–29.

Orthis jugosa James, The Palæontologist, 4, 1879, p. 31.

Dalmanella meeki Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 206, 224, pl. 5C, fig. 3.

Orthis corpulenta Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 330, pl. 5, figs. 8–10;—American Geol., XIX, 1897, p. 101, pl. 4, figs. 11–19.

Orthis (D.) testudinaria var. meeki Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 445, pl. 33, figs. 25–29.

Loc. Oxford, etc., Ohio; Spring Valley, Minnesota.

Dalmanella testudinaria multisecta (Meek). Utica (Ord.).

Orthis emacerata var. multisecta (James MS.) Meek, Pal. Ohio, I, 1873, p. 112, pl. 8, fig. 3.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 22.

Orthis multisecta Sardeson, American Geol., XIX, 1897, p. 97, pl. 4, figs. 20–23.

Dalmanella multisecta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 224.

Loc. Cincinnati, Ohio.

Dalmanella testudinaria porrecta (Sardeson). Trenton (Ord.).

Orthis porrecta Sardeson, American Geol., XIX, 1897, p. 104, pl. 5, figs. 19–24.

Loc. Near Granger, Minnesota.

Digitized by Google

DELTHYRIS Dalman. Genotype Delthyris elevata Dalman.

Delthyris Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, pp. 93, 99.—Dall, American Jour. Conch., VI, 1870, p. 116.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 9 and 16 under caption Septati (non p. 19).

Spirifera "lamellosa" Hall, Ninth Ann. Rep. New York State Geol., 1890, p. 11.

Obs. Specimens of D. elevata examined by the writer show a distinct median septum in the ventral valve.

Delthyris acanthoptera Conrad=Spirifer acanthopterus.

Delthyris acanthota Hall=Spirifer disjunctus.

Delthyris acuminata Conrad=Spirifer acuminatus.

Delthyris acuminata Hall (non Conrad)=D. mesicostalis.

Delthyris acutilirata Conrad=Platystrophia acutilirata.

Delthyris arenaria Vanuxem=Spirifer arenosus.

Delthyris arenosa Conrad=Spirifer arenosus.

Delthyris audacula Conrad=Spirifer audaculus.

Delthyris bialveata Conrad=Spirifer radiatus.

Delthyris biloba Conrad=Bilobites varicus.

Delthyris brachynota Hall=Platystrophia biforata.

Delthyris chemungensis Conrad=Spirifer disjunctus.

Delthyris congesta Hall=Spirifer granulosus.

Delthyris consobrina (d'Orbigny). Hamilton (Dev.).

Delthyris ziczac Hall (non Roemer), Geol. New York; Rep. Fourth Dist., 1843, p. 200, fig. 5.

Spirifera consobrina d'Orbigny, Prodrome Pal., I, 1850, p. 98.—Miller, N. American Geol. Pal., 1889, p. 372.

Spirifer clio Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 94.

Spirifera ziczac Hall, Pal. New York, IV, 1867, p. 222, pl. 35, figs. 15–23;—Second Ann. Rep. New York State Geol., 1883, pl. 59, fig. 9; pl. 60, fig. 18.—Whitfield, Annals New York Acad. Sci., V, 1891, p. 554, pl. 11, fig. 13;—Geol. Ohio, VII, 1895, p. 448, pl. 7, fig. 13.

Spiriferina? ziczac Whitfield, Geol. Wisconsin, IV, 1882, p. 332, pl. 25, figs. 23, 24.

Spirifer consobrinus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 34, figs. 9, 18; pl. 37, figs. 9, 10.

Loc. Moscow, York, Darien, etc., New York; Columbus, Ohio; Milwaukee, Wisconsin; Louisville, Kentucky.

Delthyris cuspidata Hall=Spirifer disjunctus.

Delthyris decemplicatus Hall=D. sulcata.

Delthyris disjuncta Hall=Spirifer disjunctus.

Delthyris duodenaria Hall=Spirifer duodenarius.

Delthyris duplicata Conrad=Spirifer duplicatus.

Delthyris euruteines Owen=Spirifer euruteines.

Delthyris expansa Owen=Pterotheca expansa, a Pteropod.

Delthyris fimbriata Conrad=Reticularia fimbriata.

Delthyris granulifera Hall=Spirifer granulosus.

Delthyris granulosa Conrad=Spirifer granulosus.

Delthyris inermis Hall=Spirifer disjunctus.

Delthyris lævis Hall=Reticularia lævis.

Delthyris lynx Hall=Platystrophia lynx and biforata.

Delthyris macronota Hall=Spirifer macronotus.

Digitized by Google

Delthyris macropleura Conrad=Spirifer macropleura.

Delthyris medialis Hall=Spirifer audaculus.

Delthyris mesicostalis Hall. Ithaca and Chemung (Dev.).

Delthyris mesacostalis Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 269, fig. 9.

Delthyris acuminata Hall (non Conrad), Ibidem, 1843, p. 270, fig. 5.

Spirifera mesacostalis Hall, Pal. New York, IV, 1867, p. 240, pl. 40, figs. 1–3.

Spirifera mesacostalis? Hall, Second Ann. Rep. New York State Geol., 1883, pl. 59, figs. 32–34.

Spirifera mesacostalis var. acuminata Hall, Ibidem, 1883, figs. 27–31.

Spirifer mesacostalis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 34, figs. 32–34.—Kindle, Bull. American Pal., 6, 1896, p. 35.

Loc. Ithaca, Philipsburg, Olean, etc., New York.

Delthyris mesastrialis Hall=Spirifer mesistrialis.

Delthyris mucronata Conrad=Spirifer pennatus.

Delthyris niagarensis Conrad=Spirifer niagaraensis.

Delthyris perlamellosa (Hall). Lower Helderberg (Dev.).

Spirifer perlamellosa Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 57, figs. 1–5 on p. 58;—Pal. New York, III, 1859, p. 201, pl. 26, figs. 1, 2.—Billings, Geol. Canada, 1863, p. 957, fig. 455.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 35, figs. 7–13.

Delthyris macropleura Rogers (non Conrad), Geol. Pennsylvania, II, Pt. II, 1858, p. 825, fig. 643.

Spirifera perlamellosa Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 384, pl. 7, fig. 9.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 60, figs. 5–13.

Spirifera perlamellosa? Keyes, Geol. Survey Missouri, V, 1895, p. 77.

Loc. Schoharie, Carlisle, etc., New York; Cumberland, Maryland; Pennsylvania; Square Lake, Maine; Perry County, Missouri; Decatur County, Tennessee.

Delthyris perlatus Conrad=Spirifer disjunctus.

Delthyris prolata Vanuxem=Spirifer disjunctus.

Delthyris prora Conrad=Spirifer acuminatus.

Delthyris radiatus Hall=Spirifer radiatus.

Delthyris raricosta Conrad. Upper Helderberg (Dev.).

Delthyris raricosta Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 262, pl. 14, fig. 18.

Delthyris undulatus Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 132, fig. 3.

Spirifer raricosta Billings, Canadian Jour., VI, 1861, p 258, figs. 71–73 on p. 259;—Geol. Canada, 1863, p. 372, fig. 392.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 135, pl. 4, fig. 2; pl. 14, fig. 12.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 35, figs. 5, 6, 14–17.

?Spirifer hesione Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 117, pl. 3, fig. 17.

Spirifera raricosta Hall, Pal. New York, IV, 1867, p. 192, pl. 27, figs. 30–34; pl. 30, figs. 1–9.—Nicholson, Pal. Prov. Ontario, 1873, p. 82.—Billings, Pal. Fossils, II, 1874, p. 47, pl. 3A, fig. 5.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 60, figs. 14–17.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 128, pl. 17, figs. 38–42.

Loc. Schoharie, Caledonia, etc., New York; Columbus, Ohio; Falls of Ohio; Eureka district, Nevada; Port Colborne, Ontario; Square Lake, Maine; Grand Greve, Gaspé.

Digitized by Google

Delthyris rugatina Conrad=D. sulcata.

Delthyris(?) rugicosta (Hall). Arisaig (Sil.).

Spirifera rugæcosta Hall, Canadian Nat. Geol., V, 1860, p. 145.—Dawson, Acadian Geol., 3d ed.; 1878, p. 596.

Loc. Arisaig, Nova Scotia.

Delthyris sculptilis Hall. Hamilton (Dev.).

Delthyris sculptilis Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 202.

Spirifera sculptilis? Billings, Canadian Jour., VI, 1861, p. 262, fig. 79.

Spirifera sculptilis Billings, Geol. Canada, 1863, p. 386, fig. 423.—Hall, Pal. New York, IV, 1867, p. 221, pl. 35, figs. 10–14.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 132, pl. 31, fig. 13.

Spirifer sculptilis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 37, fig. 8.

Loc. Ludlowville, York, etc., New York; Monroe County, Pennsylvania; Bosanquet, Ontario; Falls of Ohio.

Delthyris sinuatus Hall=Bilobites bilobus.

Delthyris staminea Hall=Spirifer crispus.

Delthyris sulcata Hisinger. Niagara (Sil.).

Delthyris sulcata Hisinger, Petref. Suecica, 1837, p. 73, pl. 21, fig. 8.

Delthyris rugatina Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 261.

Delthyris decemplicatus Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 105, fig. 4.

Spirifer sulcatus Hall, American Jour. Sci., XX, 1849, p. 228;—Pal. New York, II, 1852, p. 261, pl. 54, fig. 2.—Billings, Canadian Nat. Geol., I, 1856, p. 137, pl. 2, fig. 7.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 60, figs. 1–4.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 35, figs. 1–4.

Loc. Europe; Lockport, Rochester, etc., New York; Hamilton, Ontario.

Obs. Davidson regards this species as synonymous with D. elevata Dalman, 1828.

Delthyris undulatus Vanuxem=D. raricosta.

Delthyris varica Conrad=Bilobites varicus.

Delthyris ziczac Hall=D. consobrina.

DERBYA Waagen. Genotype Derbya regularis Waagen.

Derbyia Waagen, Palæontologica Indica, Ser. XIII, I, 1884, pp. 576, 591.

Derbya Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 261;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 286.

Derbya affinis Hall and Clarke. Upper Carboniferous.

Derbya affinis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 349, pl. 11B, figs. 4, 5.

Loc. Near Kansas City, Missouri.

Derbya bennetti Hall and Clarke. Upper Carboniferous.

Derbya bennetti Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 263, 348, pl. 11A, figs. 34–39.

Loc. Near Kansas City, Missouri.

Derbya biloba Hall. Upper Carboniferous.

Streptorhynchus biloba Hall, Second Ann. Rep. New York State Geol., 1883, pl. 41, figs. 4, 5.

Derbya biloba Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 350, pl. 11, figs. 4, 5.

Loc. Winterset, Iowa.

Digitized by Google

Derbya broadheadi Hall and Clarke. Upper Carboniferous.

Derbya broadheadi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 263, 347, pl. 11A, figs. 23, 24.

Loc. Near Kansas City, Missouri.

Derbya correanus (Derby). Upper Carboniferous.

Streptorhynchus correanus Derby, Bull. Cornell Univ., I, 1874, p. 32, pl. 6, fig. 11; pl. 7, figs. 1–4, 8, 10, 11–14, 17.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 41, figs. 18–22.

Derbya correanus Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 592.

Derbya correana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 262, pl. 11, figs. 18–22; pl. 20, figs. 10, 11.

Loc. Itaituba, Brazil.

Derbya(?) costatula Hall and Clarke. Kaskaskia (L. Carb.).

Derbya? costatula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 346, pl. 11B, figs. 16, 17.

Loc. Crittenden County, Kentucky.

Derbya crassa (Meek and Hayden). Upper Carboniferous.

Orthis arachnoides Roemer (non Phillips), Kreidebildung Texas, 1852, p. 89, pl. 11, fig. 9.—Hall, Mexican Bound. Survey, 1857, pl. 20, fig. 3.

Orthisina crassa Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1858, p. 261.

Orthis lasallensis McChesney, Descriptions New Pal. Fossils, 1860, p. 32;—Ibidem, 1865, pl. 1, fig. 6.

Orthis richmonda McChesney, Descriptions New Pal. Foss., 1860, p. 32;—Ibidem, 1865, pl. 1, fig. 5.

Hemipronites crassus Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. Knowl., XIV, 172, 1864, p. 26, pl. 1, fig. 7.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 174, pl. 5, fig. 10; pl. 8, fig. 1.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 570, pl. 25, fig. 12.—Herrick, Bull. Denison Univ., II, 1887, p. 50, pl. 2, fig. 19.

Orthis crenistria Geinitz (non Phillips), Carbon u. Dyas in Nebraska, 1866, p. 46, pl. 3, figs. 20, 21.

Hemipronites lasallensis McChesney, Trans. Chicago Acad. Sci., I, 1868, p. 28, pl. 1, fig. 6.

Hemipronites richmonda McChesney, Trans. Chicago Acad. Sci., I, 1868, p. 28, pl. 1, fig. 5.

Hemipronites crenistria White, Wheeler's Expl. Survey west 100 Merid., IV, 1875, p. 124, pl. 10, fig. 9.

Streptorhynchus richmondi Hall, Second Ann. Rep. New York State Geol., 1883, pl. 40, figs. 10, 11.

Hemipronites crassa White, Thirteenth Rep. State Geol. Indiana, 1884, p. 129, pl. 26, figs. 4–11.

Derbyia crassa Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 592.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 262, pl. 10, figs. 10, 11; pl. 11A, figs. 28–33; pl. 11B, figs. 23, 24; pl. 20, figs. 12, 13.—Smith, Proc. American Phil. Soc., XXXV, 1897, p. 28 (extract).

Streptorhynchus crenistria Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 229;—Geol. Survey Missouri, V, 1895, p. 67, pl. 38, fig. 8.

Streptorhynchus crassum Miller, N. American Geol. Pal., 1889, p. 378.

?Streptorhynchus crassum Whitfield, Annals New York Acad. Sci., V, 1891, p. 580, pl. 13, figs. 11, 12;—Geol. Ohio, VII, 1893, p. 468, pl. 9, figs. 11, 12.

Loc. Leavenworth, Kansas; Nebraska City, Nebraska; Illinois; Missouri; Iowa; Ohio; Arkansas; Utah; Nevada; northern New Mexico; San Saba Valley, Texas.

Digitized by Google

Derbya cymbula Hall and Clarke. Upper Carboniferous.

Derbya cymbula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 348, pl. 11B, figs. 2, 3.

Loc. Near Kansas City, Missouri.

Derbya kaskaskiaensis (McChesney). Kaskaskia (L. Carb.).

Orthis kaskaskiensis McChesney, Descriptions New Pal. Foss., 1860, p. 31.

Derbya kaskaskiensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 11B, fig. 6.

Loc. Kaskaskia, Chester, and Crittenden, Illinois.

Derbya keokuk Hall. Knobstone-Keokuk (L. Carb.).

Orthis crenistria Yandell and Shumard, Cont. Geol. Kentucky, 1847, pp. 19, 21.

Orthis keokuk Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 640, pl. 19, fig. 5.—Keyes, Geol. Survey Missouri, V, 1895, p. 63.

Streptorhynchus keokuk Hall, Second Ann. Rep. New York State Geol., 1883, pl. 41, figs. 1–3.

Streptorhynchus crenistria Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 279, pl. 18, fig. 14.

Derbya keokuk Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 262, pl. 11, figs. 1–3.

Loc. Keokuk, Iowa; Warsaw and Nauvoo, Illinois; New Providence, Indiana; Clark County, Missouri; Nevada.

Derbya pratteni (McChesney). Upper Carboniferous.

Orthis pratteni McChesney, Descriptions New Pal. Foss., 1860, p. 33.

Loc. Charbonier, Missouri.

Derbya robusta (Hall). Upper Carboniferous.

Orthis umbraculum? Owen (non Schloth.), Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 5, fig. 11 (see specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17945).

Orthis robusta Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 743, pl. 28, fig. 5.

Streptorhynchus robusta Hall, Second Ann. Rep. New York State Geol., 1883, pl. 40, figs. 12–17.

Derbyia robusta Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 592.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 262, pl. 10, figs. 12–17; pl. 11B, figs. 7, 8.

Loc. St. Clair County, Illinois.

Derbya ruginosa Hall and Clarke. Keokuk (L. Carb.).

Derbya ruginosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 346, pl. 11A, figs. 25–27.

Loc. New Providence, Indiana.

Dicellomus Hall=Obolella.

Dicellomus crassa Hall=Obolella crassa.

Dicellomus polita Hall=Obolella polita.

Dicœlosia King=Bilobites.

Dicraniscus Meek=Triplecia.

Dicraniscus ortoni Meek=Triplecia ortoni.

DICTYONELLA Hall. Genotype Rhynchonella? reticulata Hall.

Dictyonella Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 274.

Eichwaldia Hall, Ibidem, 1867, pp. 274–277, with figs.—Dall, American Jour. Conch., VI, 1870, p. 98.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 307;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 903.

Digitized by Google

Dictyonella anticostiensis (Billings). Anticosti (Sil.).

Eichwaldia anticostiensis Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 10.

Loc. Anticosti.

Dictyonella concinna Hall. ?Niagara (Sil.).

Eichwaldia concinna Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 278.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 83, fig. 5.

Loc. Perry and Decatur counties, Tennessee.

Dictyonella corallifera Hall. Niagara (Sil.).

Atrypa corallifera Hall, Pal. New York, II, 1852, p. 281, pl. 58, fig. 5.

Eichwaldia corallifera Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 278.

Loc. Lockport and Rochester, New York.

Dictyonella gibbosa Hall. Niagara (Sil.).

Eichwaldia gibbosa Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 278.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 83, figs. 6, 7.

Loc. Perry and Decatur counties, Tennessee.

Dictyonella reticulata Hall. Niagara (Sil.).

Rhynchonella? reticulata Hall, Trans. Albany Institute, IV, 1863, p. 217.

Eichwaldia reticulata Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, pp. 275–277, figs. 1–7;—Twenty-eighth Rep. Ibidem, 1879, p. 169, pl. 26, figs. 50–54;—Eleventh Rep. State Geol. Indiana, 1882, p. 312, pl. 26, figs. 50–54.—Foerste, Bull. Denison Univ., I, 1885, p. 91, pl. 13, fig. 4.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 31, pl. 3, figs. 11–13.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 308, figs. 229–235; pl. 83, figs. 8–13.—Foerste, Geol. Ohio, VII, 1895, p. 594, pl. 25, fig. 4.

Loc. Waldron, Indiana; Dayton, Ohio; Wisconsin.

DIELASMA King. Genotype Terebratulites elongatus Schlotheim.

Epithyris King (non Phillips), Mon. Permian Foss., Pal. Soc., 1850, p. 46.—Dall, American Jour. Conch., VI, 1870, p. 103.

Dielasma King, Proc. Dublin Univ. Zool. Bot. Assoc., I, 1859, p. 260.—Beecher and Schuchert, Biol. Soc. Washington, VIII, 1893, pp. 71–82.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 293;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 863.

Dielasma bovidens (Morton). Upper Carboniferous.

Terebratula bovidens Morton, American Jour. Sci., XXIX, 1836, p. 150, pl. 2, fig. 4.—Meek, Final Rep. U. S. Geol. Survey, Nebraska, 1872, p. 187, pl. 1, fig. 7; pl. 2, fig. 4.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 572, pl. 25, fig. 15.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 137, pl. 32, figs. 17–19.—Keyes, Geol. Survey Missouri, V, 1895, p. 105.

Terebratula bovidens? Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 711.—McChesney, Trans. Chicago Acad. Sci., I, 1869, p. 37, pl. 1, fig. 2.

Terebratula millipunctata Hall, Expl. Surveys R. R. Route Miss. River, Pacific Ocean, III, 1856, p. 101, pl. 2, figs. 1, 2;—Trans. Albany Institute, IV, 1858, p. 35.—Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p. 26.—White and St. John, Trans. Chicago Acad. Sci., I, 1868, p. 119.

Terebratula elongata Shumard (non Schlotheim), Trans. St. Louis Acad. Sci., I, 1859, p. 392.

Terebratula geniculosa McChesney, Descriptions New Pal. Foss., 1861, p. 82;—Ibidem, 1865, pl. 1, fig. 2.

Dielasma? bovidens White, Wheeler's Expl. Survey west 100 Merid., Prel. Rep., 1874, p. 21.

Digitized by Google

Dielasma bovidens (Morton)—Continued.

Terebratula (Dielasma) bovidens White, Ibidem, Final Rep., IV, 1875, p. 144, pl. 11, fig. 10.

Terebratula hastata Walcott (non Sowerby), Mon. U. S. Geol. Survey, VIII, 1884, p. 224.—Smith, Proc. American Phil. Soc., XXXV, 1897, p. 30.

Dielasma bovidens Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 295, 296, fig. 213; pl. 81, figs. 29–35.

Loc. Putnam Hill, Ohio; Indiana; Illinois; Missouri; Iowa; Nebraska; Arkansas; New Mexico; Eureka district, Nevada; Guadalupe Mountains, Texas.

Dielasma burlingtonense White. Kinderhook (L. Carb.).

Terebratula burlingtonensa White, Jour. Boston Soc. Nat. Hist., VII, 1860, p. 228.

Terebratula (Dielasma) burlingtonensis White, Wheeler's Expl. Survey west 100 Merid., IV, 1875, p. 93.

Dielasma burlingtonensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 296, pl. 81, figs. 9–11.

Loc. Burlington, Iowa; Mountain Spring, Nevada.

Dielasma calvini (Hall and Whitfield). Chemung (Dev.).

Crpytonella eudora Hall and Whitfield (non Hall, 1867), Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 225.

Cryptonella calvini Hall and Whitfield, Ibidem, 1873, p. 239.

†Cryptonella calvini Whiteaves, Cont. Canadian Pal., I, 1891, p. 235.

Dielasma calvini Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 296, pl. 80, figs. 20–22.

Loc. Hackberry Grove, Iowa; Mackenzie and Peace rivers, Canada.

Dielasma formosum Hall. Warsaw (L. Carb.).

Terebratula formosa Hall, Trans. Albany Institute, IV, 1858, p. 7.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 55, pl. 6, figs. 59–64.—White, Eleventh Rep. State Geol. Indiana, 1882, p. 361, pl. 39, figs. 6–8.—Hall, Twelfth Rep. Ibidem, 1883, p. 337, pl. 29, figs. 59–64.

Dielasma formosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 296, pl. 81, figs. 12–26.

Loc. Bloomington and Spergen Hill, Indiana; Alton and Warsaw, Illinois; Caldwell County, Kentucky.

Dielasma gorbyi (Miller). Keokuk (L. Carb.).

Terebratula gorbyi Miller, Seventeenth Rep. State Geol. Indiana, 1891, p. 77, pl. 13, figs. 3, 4.

Loc. Edwardsville and Crawfordsville, Indiana.

Dielasma hochstetteri (Toula). Upper Carboniferous.

Terebratula hochstetteri Toula, Sitzb. der k. k. Akad. der Wissensch. zu Wien, LIX, 1869, p. 1, pl. 1, fig. 1.—Derby, Bull. Cornell Univ., I, 1874, p. 63.

Loc. Near Cochabamba, Bolivia.

Obs. Probably synonymous with D. bovidens (Morton).

Dielasma itaitubaense (Derby). Upper Carboniferous.

Terebratula itaitubensis Derby, Bull. Cornell Univ., I, 1874, p. 1, pl. 2, figs. 1, 3, 8, 16; pl. 3, fig. 24; pl. 6, fig. 15.

Dielasma itaitubensis Waagen, Palæontologica Indica, Ser. XIII, I, 1882, p. 348.—de Koninck, Annales du Musée Royal d'Histoire Naturelle de Belgique, XIV, 1887, p. 26, pl. 5, figs. 1–10, 45, 50.

Loc. Beach at Itaituba, Brazil; Belgium.

Digitized by Google

Dielasma obovatum Hall and Clarke. ?Upper Carboniferous.

Dielasma obovata Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 81, figs. 38-40.

Loc. Kentucky.

Dielasma occidentale (Miller). Chouteau (L. Carb.).

Terebratula occidentalis Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 313, pl. 9, figs. 10-13.

Loc. Sedalia, Missouri.

Dielasma(?) rowleyi (Worthen). Burlington (L. Carb.).

Terebratula rowleyi Worthen, Bull. Illinois State Mus. Nat. Hist., 2, 1884, p. 23;—Geol. Survey Illinois, VIII, 1890, p. 102, pl. 11, fig. 6.—Keyes, Geol. Survey Missouri, V, 1895, p. 105, pl. 40, fig. 15.

Dielasma rowleyi Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 296, pl. 81, figs. 27, 28.

Loc. Pike County, Missouri.

Dielasma sacculus (Martin). Upper Carboniferous.

Conchyliolithus anomites sacculus Martin, Petref. Derbesiana, 1809, tab. 46, figs. 1, 2.

Terebratula sacculus Dawson, Acadian Geol., 1855, p. 219, fig. 27.—Davidson, Quart. Jour. Geol. Soc. London, XIX, 1863, p. 169, pl. 9, figs. 1-3.—Dawson, Acadian Geol., 3d ed., 1878, p. 289, fig. 87.

Loc. Europe; Windsor, Nova Scotia.

Dielasma shumardianum (Miller). Kaskaskia (L. Carb.).

Terebratula arcuata Swallow (non Roemer, 1840), Trans. St. Louis Acad. Sci., II, 1863, p. 83.—Meek, Sixth Ann. Rep. U. S. Geol. Survey Terr., 1872, p. 470.

Terebratula shumardana Miller, American Pal. Foss., 2d ed., 1883, p. 299.

Loc. St. Genevieve County, Missouri; Chester, Illinois; near Virginia City, Montana.

Obs. Regarded by Meek and White as probably synonymous with D. bovidens (Morton).

Dielasma turgidum (Hall). Warsaw and St. Louis (L. Carb.).

Terebratula turgida Hall, Trans. Albany Institute, IV, 1858, p. 6.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 54, pl. 6, figs. 53-58.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 336, pl. 29, figs. 53-58.—Whitfield, Annals New York Acad. Sci., V, 1891, p. 586, pl. 13, figs. 21, 22;—Geol. Ohio, VII, 1895, p. 473, pl. 9, figs. 21, 22.

Dielasma turgida Beecher and Schuchert, Proc. Biol. Soc. Washington, VIII, 1893, p. 73, pl. 10, figs. 1-6.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 296, pl. 81, figs. 1-8.

Loc. Bloomington and Spergen Hill, Indiana; Crittenden County, Kentucky; Maxville and Newtonville, Ohio; Alton and Warsaw, Illinois; Pella, Iowa; Boonville, Missouri.

DIGNOMIA Hall. Genotype Lingula alveata Hall.

Dignomia Hall, Notes on some New or Imperfectly Known Forms among the Brach., 1872, p. 2, pl. 13, fig. 3;—Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 245, pl. 13, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 14, 163;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 230.

Dignomia alveata Hall. Hamilton (Dev.).

Lingula alveata Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 23;—Pal. New York, IV, 1867, p. 12, pl. 2, figs. 14, 15.

Digitized by Google

Dignomia alveata Hall—Continued.

Dignomia alveata Hall, Notes on some New or Imperfectly Known Forms among the Brach., 1872, p. 2, pl. 13, fig. 3;—Twenty-third Rep. New York State Cab. Nat. Hist., 1873, pl. 13, fig. 3.—Hall and Clarke, Pal. New York, VIII. Pt. I, 1892, p. 14, pl. 1, figs. 24, 25.—Clarke, Thirteenth Ann. Rep. New York State Geologist, 1895, p. 187, pl. 4, fig. 1.

Loc. Canandaigua Lake, etc., New York.

DINOBOLUS Hall. Genotype Obolus conradi Hall.

Dinobolus Hall, Notes on some New or Imperfectly Known Forms among the Brach., (March) 1871, p. 4;—Ibidem, 1872, p. 4;—Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 247.—Hall and Whitfield, Pal. Ohio, II, 1873, p. 130.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 36, 46, 164;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 237.

Obolellina Billings, Canadian Nat. Geol., VI (December) 1871, p. 222;—Ibidem, VI, 1872, p. 326, figs. 1, 2;—American Jour. Sci., 3d ser., III, 1872, p. 270.

Conradia Hall (non Adams), Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 250.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 159.

Dinobolus canadaensis (Billings). Black River and Trenton (Ord.).

Obolus canadensis Billings, Canadian Nat. Geol., III, 1858, p. 441, fig. 20–23 (non fig. 19 = D. magnificus);—Geol. Survey Canada; Rep. Prog. for 1857, 1858, p. 189, figs. 20–23 (non fig. 19);—Geol. Canada, 1863, p. 142, figs. 75.

Obolellina canadensis Billings, Canadian Nat. Geol., VI, 1871, p. 222;—Ibidem, 1872, p. 326, fig. 15; fig. 6, p. 329.

Dinobolus canadensis Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 162, pl. 19, fig. 7.

Loc. Pauquette Rapids, etc., Canada.

Dinobolus conradi Hall. Niagara (Sil.).

Obolus conradi Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1868, p. 368, pl. 13, figs. 1, 2.

Obolus (Trimerella?) conradi Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 351, pl. 5, fig. 7.

Trimerella conradi Dall, American Jour. Conch., VII, 1871, p. 83.

Dinobolus conradi Hall, Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 247 (also extracts 1871, 1872).—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 160, pl. 18, figs. 1–5.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 130, pl. 7, figs. 3, 4.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 38, pl. 4B, figs. 13–24.

Loc. Port Byron, Illinois; Leclaire, Iowa; Racine and Grafton, Wisconsin; Crawford, Ohio; England; Gotland.

Dinobolus magnificus (Billings). Black River-Trenton (Ord.).

Obolus canadensis Billings (partim), Geol. Surv. Canada, Rep. Prog. for 1857, 1858, p. 189, fig. 19 (non 20–23);—Canadian Nat. Geol., III, 1858, p. 441, fig. 19 (non figs. 20–23 = D. canadensis).

Obolellina magnificus Billings, Ibidem, n. ser., VI, 1872, p. 329, fig. 7.

Dinobolus magnificus Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 164, pl. 19, fig. 8.—Nicholson, Pal. Prov. Ontario, 1875, p. 17, fig. 6.

Loc. Pauquette Rapids, etc., Canada.

Dinobolus(?) parvus Whitfield. Galena (Ord.).

Dinobolus? parvus Whitfield, Geol. Wisconsin, IV, 1882, p. 347, pl. 27, figs. 8–10.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 356, fig. 27.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 166.

Loc. Whitewater, Wisconsin; Wykoff, Minnesota; Lake Winnipeg, Canada.

Digitized by Google

DINORTHIS Hall and Clarke. Genotype Orthis pectinella Emmons.

Dinorthis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 195, 222.—Winchell and Schuchert, Minnesota Geol. Survey; III, 1893, p. 420.

Plæsiomys Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 196.

Dinorthis and Plæsiomys Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 266.

Dinorthis deflecta (Conrad.) Trenton (Ord.).

Strophomena deflecta Conrad, Proc. Acad. Nat Sci. Philadelphia, I, 1843, p. 332.—Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 70.

Strophomena recta Conrad, Proc. Acad. Nat. Sci. Philadelphia, I, 1843, p. 332.—Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 70.

Leptæna deflecta Hall, Pal. New York, I, 1847, p. 113, pl. 31B, fig. 5.

Leptæna recta Hall, Ibidem, 1847, p. 113, pl. 31B, fig. 6.

Streptorhynchus rectus Miller, American Pal. Foss., 1877, p. 134.

Streptorhynchus deflectum Miller, N. American Geol. and Pal., 1889, p. 378.

Plæsiomys deflecta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 197, 222, pl. 5A, figs. 28–34.

Plæsiomys recta Hall and Clarke, Ibidem, 1892, pp. 197, 222.

Plæsiomys loricula Hall and Clarke, Ibidem, 1892, pp. 197, 341, pl. 5A, figs. 31–34.

Orthis (Dinorthis) deflecta Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 422, pl. 32, figs. 24–30.

Loc. Mineral Point, Beloit, Janesville, Wisconsin; Dixon, Illinois; Minneapolis, St. Paul, etc., Minnesota; McGregor, Iowa; central Tennessee; Highbridge, Kentucky.

Dinorthis fontinalis (White). Calciferous (Ord.).

Strophomena fontinalis White, Wheeler's Expl. and Survey west 100th Merid., IV, 1875, p. 54, pl. 3, fig. 4;—Prelim. Rep., p. 10, 1874.

Loc. Fish Spring, House Range, Utah.

Obs. Related to D. deflecta (Conrad).

Dinorthis iphigenia (Billings). Trenton (Ord.).

Orthis iphigenia Billings, Pal. Fossils, I, 1862, p. 133, pl. 110.

Plæsiomys iphigenia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Loc. Ottawa, Canada.

Dinorthis meedsi Winchell and Schuchert. Trenton (Ord.).

Orthis meedsi Winchell and Schuchert, American Geol., IX, April 1, 1892, p. 289.

Orthis minnesotensis Sardeson, Bull. Minnesota Acad. Nat. Sci., III, April 9, 1892, p. 332, pl. 5, figs. 14–17.

Orthis (Dinorthis) meedsi Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 427, pl. 32, figs. 39–42.

Loc. Cannon Falls, Kenyon, Preston, etc., Minnesota; Decorah and McGregor, Iowa; Neenah and Oshkosh, Wisconsin.

Dinorthis meedsi germana Winchell and Schuchert. Trenton (Ord.).

Orthis meedsi var. germana Winchell and Schuchert, American Geol., IX, 1892, p. 290.

Orthis (D.) meedsi var. germana Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 428, pl. 32, figs. 43–45.

Loc. Cannon Falls, Kenyon, and Fountain, Minnesota.

Dinorthis pectinella (Emmons). Trenton (Ord.).

Orthis pectinella Emmons, Geol. New York; Rep. Second Dist., 1842, p. 394, fig. 2.—Hall, Pal. New York, I, 1847, p. 123, pl. 32, fig. 10.—Billings, Canadian Nat. Geol., I, 1856, p. 205, fig. 5 —Rogers, Geol. Pennsylvania, II, Pt. II,

Digitized by Google

Dinorthis pectinella (Emmons)—Continued.

1858, p. 818, fig. 602.—Billings, Geol. Canada, 1863, p. 165, fig. 147.—Hall, Second Ann Rep. New York State Geol., 1883, pl. 34, figs. 39, 40.

Orthis pectinella var. semiovalis Hall, Pal. New York, I, 1847, p. 124, pl. 32, fig. 11.—Miller, N. American Geol. Pal., 1889, p. 359.

Orthis charlottæ N. H. Winchell, Eighth Rep. Geol. Nat. Hist. Survey Minnesota, 1880, p. 67.

Dinorthis pectinella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 195, 222, 228, pl. 5, figs. 27–33

Orthis (Dinorthis) pectinella Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 424, pl. 32, figs. 31–34.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 175.

Loc. Middleville, Trenton Falls, etc., New York; Pennsylvania; Mercer County, Kentucky; Ontario, Canada; Decorah, Iowa; St. Paul, Minneapolis, and Cannon Falls, Minnesota; Lake Winnipeg, Canada.

Dinorthis pectinella sweeneyi N. H. Winchell. Trenton (Ord.).

Orthis sweeneyi N. H. Winchell, Ninth Rep. Geol. Nat. Hist. Survey Minnesota, 1881, p. 117.

Dinorthis sweeneyi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 196, 222, 228, pl. 5, figs. 34–36.

Orthis (Dinorthis) pectinella var. sweeneyi Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 426, pl. 32, figs. 35–38.

Loc. St. Paul, Cannon Falls, etc., Minnesota; Decorah and McGregor, Iowa.

Dinorthis platys (Billings). Chazy (Ord.).

Orthis platys Billings, Canadian Nat. Geol., IV, 1859, p. 438, fig. 15;—Geol. Canada, 1863, p. 129, fig. 54.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 218.

Loc. Island of Montreal, Canada.

Dinorthis porcata (McCoy). Trenton and Lorraine (Ord.).

Orthis porcata McCoy, Silurian Foss. of Ireland, 1846, p. 32, pl. 3, fig. 14.—Billings, Pal. Fossils, I, 1862, p. 135, fig. 111;—Geol. Canada, 1863, p. 312, fig. 319.

Orthis anticostiensis Shaler, Fossil Brachiopoda of the Ohio Valley, 1887, p. 19, pl. 6.

Plesiomys porcata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 197, 222, pl. 5A, figs. 20, 21.

Loc. Ireland; Ottawa, Canada; Anticosti.

Dinorthis proavita Winchell and Schuchert. Lorraine (Ord.).

Orthis proavita Winchell and Schuchert, American Geol., IX, April 1, 1892, p. 290.

Orthis petræ Sardeson, Bull. Minnesota Acad. Nat. Sci., III, April 9, 1892, p. 332, pl. 5, figs. 18–21.

Orthis (Dinorthis) proavita Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 431, pl. 32, figs. 51–57.—? Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 176.

Loc. Spring Valley, Minnesota; Wilmington, Illinois; Lake Winnipeg, Canada.

Dinorthis retrorsa (Salter). Trenton and Lorraine (Ord.).

Orthis retrorsa Salter, Mem. Geol. Survey Great Britain, II, 1858, p. 373, pl. 27, figs. 3, 4.—Billings, Pal. Fossils, I, 1862, p. 136, figs. 112, 113.—Meek, Pal. Ohio, I, 1873, p. 92, pl. 11, fig. 7.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 37.

Orthis carleyi Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 120, fig. in text;—Second Ann. Rep. New York State Geol., 1883, pl. 34, figs. 28, 29.

Orthis kennicotti McChesney, New Pal. Fossils, 1861, p. 78.

Digitized by Google

Dinorthis retrorsa (Salter)—Continued.

Plæsiomys retrorsa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 197, 222, pl. 5A, figs. 14–16.

Loc. England; Oxford, etc., Ohio; Ottawa, Canada.

Dinorthis subquadrata (Hall). Lorraine (Ord.).

Orthis subquadrata Hall, Pal. New York, I, 1847, p. 126, pl. 32A, fig. 1;—Geol. Wisconsin, I, 1862, p. 54, figs. 1, 2.—Meek, Pal. Ohio, I, 1873, p. 94, pl. 9, fig. 2.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 38.—White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, p. 484, pl. 1, figs. 3–5;—Tenth Rep. State Geol. Indiana, 1881, p. 116, pl. 1, figs. 3–5.—Shaler, Foss. Brachiopoda of the Ohio Valley, 1887, p. 22, pl. 7.—Keyes, Geol. Survey Missouri, V, 1895, p. 60.

?Orthis subquadrata Billings, Geol. Canada, 1863, p. 165, fig. 146.

Plæsiomys subquadrata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 191, 196, 222, pl. 5A, figs. 17-19.

Orthis (Dinorthis) subquadrata Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 428, pl. 32, figs. 46–50.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 176.

Loc. Ohio Valley; Spring Valley, Minnesota; Wilmington, Illinois; Warren and Jefferson counties, Missouri; Lattners, Iowa; Iron Ridge, Wisconsin; Lake Winnipeg, Canada; Anticosti.

Discina of authors (non Lamarck)=Orbiculoidea.

Discina acadica Hartt=Parmophorella acadica, a gastropod.

Discina alleghania Hall=Orbiculoidea alleghania.

Discina ampla Hall=Orbiculoidea ampla.

Discina capax White=Orbiculoidea capax.

Discina capuliformis McChesney=Orbiculoidea capuliformis.

Discina circe Billings=Orbiculoidea lamellosa.

Discina clara Spencer=Schizotreta tenuilamellata.

Discina concordensis Sardeson=Schizotreta pelopea.

Discina connata Walcott=Lingulodiscina connata.

Discina conradi Hall=Orbiculoidea conradi.

Discina convexa Shumard=Orbiculoidea convexa.

Discina discus Hall=Orbiculoidea discus.

Discina doria Hall=Orbiculoidea doria.

Discina elmira Hall=Orbiculoidea elmira.

Discina forbesi Nicholson=Schizotreta tenuilamellata.

Discina gallaheri Winchell=Orbiculoidea gallaheri.

Discina grandis Vanuxem=Rœmerella grandis.

Discina grandis Hall=Orbiculoidea ampla.

Discina humilis Hall=Orbiculoidea humilis.

?Discina inutilis Hall. Upper Cambrian.

Discina inutilis Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 130, pl. 6, fig. 11;—Trans. Albany Institute, V, 1867, p. 108.

Loc. Mazomanie, Wisconsin.

Obs. Undeterminable.

Discina illinoisensis Miller and Gurley=Orbiculoidea illinoisensis.

Discina jervensis Barret=Orbiculoidea jervisensis.

Digitized by Google

Discina keokuk Gurley=Orbiculoidea keokuk.
Discina lodensis Hall=Orbiculoidea lodiensis.
Discina magnifica Herrick=Orbiculoidea magnifica.
Discina manhattensis Meek and Hayden=Orbiculoidea manhattanensis.
Discina marginalis Whitfield=Orbiculoidea marginalis.
Discina media Hall=Orbiculoidea lodiensis media.
Discina meekana Whitfield=Orbiculoidea missouriensis.
Discina microscopica Shumard=Acrotreta microscopica.
Discina minuta Hall=Orbiculoidea minuta.
Discina missouriensis Shumard=Orbiculoidea missouriensis.
Discina munda Miller and Gurley=Orbiculoidea munda.
Discina neglecta Hall=Orbiculoidea neglecta.
Discina newberryi Hall=Lingulodiscina newberryi.
Discina nitida Meek and Worthen=Orbiculoidea missouriensis.
Discina nitida=Orbiculoidea nitida.
Discina patellaris Winchell=Orbiculoidea patellaris.
Discina pelopea Billings=Schizotreta pelopea.

Discina(?) pileolus Whiteaves. ? Lower Cretaceous.

Discina pileolus Whiteaves, Cont. Canadian Pal., I, 1889, p. 159, pl. 21, fig. 3.
Loc. Rink Rapids on Lewis River, British America.
Obs. "Professor Hyatt thinks that the fossils from this locality are Jurassic" (Stanton).

Discina pleurites Meek=Lingulodiscina pleurites.
Discina randalli Hall=Orbiculoidea randalli.
Discina saffordi Winchell=Orbiculoidea saffordi.
Discina sampsoni Miller=Orbiculoidea sampsoni.

Discina(?) semipolita Whiteaves. Cretaceous.

Discina semipolita Whiteaves, Mesozoic Fossils, I, Geol. Survey Canada, 1884, p. 252, pl. 33, fig. 9.
Loc. Queen Charlotte Island.

Discina seneca Hall=Orbiculoidea senoca.
Discina solitaria Ringueberg=Schizotreta tenuilamellata.

?Discina sublamellosa Ulrich. Lorraine (Ord.).

Discina sublamellosa Ulrich, Jour. Cincinnati, Soc. Nat. Hist., I, 1878, p. 97, pl. 4, fig. 11.—Miller, N. American Geol. Pal., 1889, p. 344.
Loc. Covington, Kentucky.
Obs. Probably not a brachiopod.

Discina subtrigonalis McChesney=Orbiculoidea subtrigonalis.
Discina tenuilamellata var. subplana Hall=Orbiculoidea subplana.
Discina tenuilineata Meek and Hayden=Orbiculoidea tenuilineata.
Discina tenuistriata Ulrich=Orbiculoidea tenuistriata.
Discina trigonalis McChesney=Orbiculoidea subtrigonalis.
Discina truncata Hall=Schizobolus concentricus.
Discina truncata Emmons=Orbiculoidea lamellosa.
Discina tullia Hall=Orbiculoidea tullia.
Discina utahensis Meek=Orbiculoidea utahensis.

Digitized by Google

Discina(?) vancouverensis Whiteaves. Cretaceous.

Discina vancouverensis Whiteaves, Mesozoic Fossils, I, Geol. Survey Canada, 1879, p. 177, pl. 20, fig. 6.

Loc. Admiralty Island.

Discina vanuxemi Hall=Orbiculoidea vanuxemi.

Discina varsoviensis Worthen=Orbiculoidea varsaviensis.

Discinella Hall=Operculum of Pteropod.

DISCINISCA Dall. Genotype Discina lamellosa Broderip.

Discinisca Dall, Bull. Mus. Comp. Zoology, III, 1871, p. 37.

Discinisca lugubris (Conrad). Miocene and Pliocene.

Capulus lugubris Conrad, Jour. Acad. Nat. Sci. Philadelphia, VII, 1834, p. 143.

Orbicula lugubris Conrad, Fossils Medial Tertiary For. U. S., 1845, p. 75, pl. 43, fig. 2.—Tuomey and Holmes, Foss. South Carolina, 1855, p. 17, pl. 5, fig. 1.—Dall, Republication of Conrad's Foss. Medial Tert. For. U. S., 1893, p. 101, pl. 43, fig. 2.

Discina lugubris, Whitfield, Mon. U. S. Geol. Survey, XXIV, 1894, p. 23, pl. 1, figs. 1–3.

Loc. St. Marys County, Maryland; Petersburg, Virginia; Peedee River, South Carolina; Atlantic City, Shiloh, and Bridgeton, New Jersey.

Obs. Referred to Discinisca on authority of Dr. W. H. Dall.

Discinisca multilineata (Conrad). Miocene.

Orbicula multilineata Conrad, Fossils Medial Tertiary For. U. S., 1845, p. 75, pl. 43, fig. 3.—Tuomey and Holmes, Foss. South Carolina, 1855, p. 18, pl. 5, fig. 2.—Dall, Republication of Conrad's Foss. Medial Tert. For. U. S., 1893, p. 101, pl. 43, fig. 3.

Loc. City Point, Virginia; Pedee River, South Carolina.

Obs. Probably a less worn variety of D. lugubris (Dall).

DISCINOPSIS Matthew. Genotype Acrotreta? gulielmi Matthew.

Discinopsis (Matthew MS.) Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 105, 167;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 250.

Discinopsis gulielmi Matthew. Middle Cambrian.

Acrotreta? gulielmi Matthew, Trans. Royal Soc. Canada, 1886, p. 37, pl. 5, fig. 14.

Discinopsis gulielmi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 105, pl. 3, figs. 20–24.

Loc. Portland, New Brunswick.

EATONIA Hall. Genotype Atrypa peculiaris Conrad.

Eatonia Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 90;—Twelfth Rep. Ibidem, 1859, p. 35;—Pal. New York, III, 1859, p. 432.—Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 111.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 205;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 829.

Eatonia coulteri Miller and Gurley. Oriskany (Dev.).

Eatonia coulteri Miller and Gurley, Bull. Illinois State Mus. Nat. Hist., 3, 1893, p. 72, pl. 7, figs. 8–11.

Loc. Jackson County, Illinois.

Eatonia eminens Hall. Lower Helderberg (Dev.).

Eatonia eminens Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 92;—Pal. New York, III, 1859, p. 242, pl. 37, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 206.

Loc. Decatur County, Tennessee.

Digitized by Google

Eatonia medialis (Vanuxem). Lower Helderberg (Dev.).

Atrypa medialis Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 120, fig. 4.

Eatonia medialis Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 90, figs. 1–7;—Pal. New York, III, 1859, p. 241, pl. 37, fig. 1.—Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 111, pl. 3, fig. 7.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 206, pl. 61, figs. 29–35.

Loc. Schoharie, Carlisle, Catskill, etc., New York; Square Lake, Maine.

Eatonia peculiaris (Conrad). Lower Helderberg and Oriskany (Dev.).

Atrypa peculiaris Conrad, Fifth Ann. Rep. Geol. Survey New York, 1841, p. 56.—Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 123, fig. 3.—Hall, Ibidem, Rep. Fourth Dist, 1843, p. 148, fig. 3.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 825, fig. 640.

Atrypa? nustella Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 39, pl. 14, fig. 3.

Eatonia peculiaris Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 37, figs. 1–7;—Pal. New York, III, 1859, p. 244, pl. 38, figs. 21–26; pl. 51, fig. 2; p. 436, pl. 101, fig. 2; pl. 101A, fig. 1;—Fifteenth Rep. New York State Cab. Nat. Hist., 1862, pl. 11.—Billings, Geol. Canada, 1863, p. 957, fig. 450.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 395, pl. 8, fig. 2.—Billings, Pal. Fossils, II, 1874, p. 40, pl. 3A, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 206, pl. 61, figs. 17–26.

Eatonia peculiaris? Keyes, Geol. Survey Missouri, V, 1895, p. 104.

Loc. Schoharie, etc., New York; Pennsylvania; Cumberland, Maryland; Jackson and Perry counties, Missouri; Gaspé.

Eatonia pumila Hall. Oriskany (Dev.).

Eatonia pumila Hall, Pal. New York, III, 1859, p. 437, pl. 101, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 206.

Loc. Albany County, New York.

Eatonia singularis (Vanuxem). Lower Helderberg (Dev.).

Atrypa singularis Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 120, fig 3.

Eatonia singularis Hall, Pal. New York, III, 1859, p. 242, pl. 38, figs. 14–20.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 206, pl. 61, figs. 13–16.

Loc. Schoharie, etc., New York.

Eatonia sinuata Hall. Oriskany (Dev.).

Eatonia sinuata Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 91;—Pal. New York, III, 1859, p. 438, pl. 101A, figs. 3–6.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 206, pl. 61, figs. 36–38.

Loc. Cumberland, Maryland.

Eatonia(?) variabilis Whiteaves. Hamilton (Dev.).

Eatonia variabilis Whiteaves, Cont. to Canadian Pal., I, 1891, p. 233, pl. 29, figs. 6–9.

Loc. Hay River, Canada.

Eatonia whitfieldi Hall. Oriskany (Dev.).

Eatonia whitfieldi Hall, Pal. New York, III, 1859, p. 437, pl. 101A, fig. 2.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 206, pl. 61, figs. 27, 28.

Loc. Cumberland, Maryland.

EICHWALDIA Billings. Genotype Eichwaldia subtrigonalis Billings.

Eichwaldia Billings, Geol. Survey Canada; Rep. Progress for 1857, 1858, p. 190;—Canadian Nat. Geol., III, 1858, p. 442.

Eichwaldia of other authors=Dictyonella.

Digitized by Google

Eichwaldia subtrigonalis Billings. Trenton (Ord.).

Eichwaldia subtrigonalis Billings, Geol. Survey Canada; Rep. Progress for 1857, 1858, p. 192, fig. 24;—Canadian Nat. Geol., III, 1858, p. 443, fig. 24;—Geol. Canada, 1863, p. 142, fig. 76.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 310, figs. 241, 242; pl. 83, figs. 1–4.

Loc. Pauquette Rapids, Canada.

ELKANIA Ford. Genotype Obolella desiderata Billings.

Billingsia Ford (non de Koninck, 1876), American Jour. Sci., 3d ser., XXXI, 1885, p. 466.

Elkania Ford, American Jour. Sci., 3d ser., XXXII, 1886, p. 325.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 75, 165;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 241.

Elkania ambigua (Walcott). Pogonip (base of Ord.).

Obolella? ambigua Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 67, pl. 1, fig. 2.

Elkania ambigua Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 78.

Loc. Eureka district, Nevada.

Elkania desiderata (Billings). Upper Cambrian.

Obolella desiderata Billings, Pal. Fossils, I, 1862, p. 69, fig. 62 on p. 68.

Obolella? desiderata Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 111.

Billingsia desiderata Ford, American Jour. Sci., 3d ser., XXXI, 1886, p. 466, figs. 1, 2.

Elkania desiderata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 77, pl. 3, figs. 15–19.

Loc. Point Levis, Canada.

ENTELETES Fischer de Waldheim. Genotype Orthis lamarcki Fisch.

Enteletes Fischer de Waldheim, Oryct. Gouv. Moscou, 1830, p. 193, tab. 26, figs. 6, 7.—Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 550.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 185, 214;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 272.

Syntrielasma Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 277;—Geol. Survey Illinois, II, 1866, p. 321, fig. 36.

Enteletes andii (d'Orbigny). Upper Carboniferous.

Terebratula andii d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 45, pl. 3, figs. 14, 15.

Orthis andii Salter, Quart. Jour. Geol. Soc. London, XVII, 1861, p. 64, pl. 4, fig. 3.

Syntrielasma andii Derby, Bull. Cornell Univ., I, 1874, p. 62.

Rhynchonella andii Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., VIII, 1881, p. 302.

Enteletes andii Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217.

Loc. Yarbichambi and Lake Titicaca, Bolivia; Santa Cruz.

Enteletes gaudryi (d'Orbigny). Upper Carboniferous.

Terebratula gaudryi d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 45.

Terebratula antisiensis d'Orbigny, Ibidem, 1842, pl. 3, fig. 16 (non pl. 2).

Syntrielasma gaudryi Derby, Bull. Cornell Univ., I, 1874, p. 62.

Enteletes gaudryi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217.

Loc. Yarbichambi, Bolivia.

Enteletes hemiplicata Hall. Upper Carboniferous.

Spirifer hemiplicata Hall, Stansbury's Exped. Great Salt Lake, 1852, p. 409, pl. 4, fig. 3.

Digitized by Google

Enteletes hemiplicata Hall—Continued.

Rhynchonella angulata Geinitz (non Linné), Carbon u. Dyas Nebraska, 1866, p. 37, pl. 3, figs. 1–4.

Syntrielasma hemiplicata Meek and Worthen, Geol. Survey Illinois, II, 1866, p. 323, fig. 36; p. 324, fig. 37.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 177, pl. 6, fig. 1; pl. 8, fig. 12.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 571, pl. 26, fig. 20.—Kayser, Richthofens China, IV, 1883, p. 179, pl. 24, figs. 2, 3.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 131, pl. 26, figs. 15–18.—Keyes, Geol. Survey Missouri, V, p. 76, pl. 39, fig. 8.

Camerophoria giffordi Worthen, Bull. Illinois State Mus., 1, 1882, p. 39;—Geol. Survey Illinois, VII, 1883, p. 318, figs. a–c.

Enteletes hemiplicata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 215, 226, pl. 7A, figs. 44–52.

Loc. Weston, Platte County, Missouri; Vandalia and Alta, Illinois; Stennett, Iowa; Kansas City, Missouri; Nebraska City, Nebraska; Lo Ping, China.

EUMETRIA Hall.

Genotype Retzia verneuiliana Hall=Terebratula marcyi Shumard.

Eumetria Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 59.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 487.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 115, figs. 104, 105;—Thirteenth Ann. Rep. New York State Geol., 1895, p. 795.

Eumetria(?) altirostris (White). Kinderhook (L. Carb.).

Retzia (Acambona?) altirostris White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 28.

Loc. Burlington, Iowa.

Eumetria marcyi (Shumard). St. Louis and Kaskaskia (L. Carb.).

Terebratula serpentina? Owen (non de Koninck), Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 3A, fig. 13 (see specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17955).

Terebratula marcyi Shumard, Marcy's Rep. U. S. Expl. Red River of Louisiana, 1854, p. 177, pl. 1, fig. 4.

Retzia verneuiliana Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 657, pl. 23, fig. 1;—Trans. Albany Institute, IV, 1858, p. 9.

Retzia vera Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 704, pl. 27, fig. 3.

Eumetria vera Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 55, figs. 1–3, and p. 59.

Eumetria verneuiliana Hall, Ibidem, 1863, p. 55, fig. 2.—Whitfield, Bull. American Mus. Nat. Hist., 1882, p. 50, pl. 6, figs. 28–30.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 335, pl. 29, figs. 28–30.

Retzia radialis Walcott (non Phillips), Mon. U. S. Geol. Survey, VIII, 1884, p. 220, pl. 7, figs. 5, 5a (5b?).

Retzia marcyi Miller, N. American Geol. Pal., 1889, p. 366.

Eumetria verneuiliana and vera Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 117, figs. 104, 105, pl. 50, figs. 13–26, 34, 37; pl. 83, figs. 26, 27.

Loc. Washington and Crawford counties, Arkansas; Floyd County and elsewhere in Indiana; Alton, Illinois; Greene County, Missouri; Iowa; Cumberland Mountain, Tennessee.

Obs. Hall and Clarke (1893), in treating of the American species of Eumetria (E. vera and var. costata, and E. verneuiliana), say they "are, perhaps, all representatives of the same species." The writer regards them as one species, varying in different localities in size and number of striations. Owen was the first to observe this form and identified it provisionally with T. serpentina de Koninck. Shumard, however, believed it to be distinct from that species, and gave the name T. marcyi four years prior to that of Hall.

Digitized by Google

Eumetria marcyi costata Hall. Kaskaskia (L. Carb.).

Retzia vera var. costata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 704, pl. 27, fig. 3.

Eumetria vera var. costata Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 51, figs. 27–33.

Loc. Chester, Illinois; Crittenden County, Kentucky.

Eumetria vera Hall = E. marcyi.

Eumetria verneuiliana Hall = E. marcyi.

Eumetria woosteri (White). ? Upper Carboniferous.

Retzia woosteri White, Bull. U. S. Geol. Survey Terr., V, 1879, p. 215;—Twelfth Ann. Rep. U. S. Geol. Survey Terr., 1883, p. 134, pl. 34, fig. 8.

Loc. Near Greeley, Colorado.

Obs. Closely related with E. marcyi of the Lower Carboniferous.

EUNELLA Hall and Clarke. Genotype Terebratula sullivanti Hall.

Eunella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 290;—Thirteenth Ann. Rep. New York State Geol., 1895, p. 861.

Eunella harmonia Hall. Corniferous (Dev.).

Terebratula harmonia Hall, Pal. New York, IV, 1867, p. 388, pl. 60, figs. 11–16.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 154, pl. 17, figs. 1–4.

Eunella harmonia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 290, pl. 80, figs. 33–35.

Loc. Falls of Ohio; Ontario, Canada.

Eunella lincklæni Hall. Marcellus and Hamilton (Dev.).

Terebratula lincklæni Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 88;—Pal. New York, IV, 1867, corrigenda.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 155, pl. 17, figs. 22–24.

Cryptonella lincklæni Hall, Fourteenth Rep. New York State Cab. Nat. Hist., 1861, p. 101;—Sixteenth Rep. Ibidem, 1863, p. 44.

Cryptonella? lincklæni Hall, Pal. New York, IV, 1867, p. 397, pl. 60, figs. 49–65.

Terebratula lincklæni var. Hall, Ibidem, 1867, p. 418, pl. 60, figs. 32–37.

Eunella lincklæni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 290, pl. 80, figs. 28–32.

Loc. Clarke County, Indiana; Hamilton and Canandaigua Lake, New York; Thunder Bay, Michigan.

Eunella simulator Hall. Hamilton (Dev.).

Terebratula simulator Hall, Pal. New York, IV, 1867, p. 391, pl. 60, figs. 69, 70.

Eunella simulator Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 290, pl. 80, fig. 27.

Loc. Thedford, Ontario.

Eunella sullivanti Hall. Corniferous (Dev.).

Terebratula sullivanti Hall, Pal. New York, IV, 1867, p. 387, pl. 60, figs. 5–10, 68.—Whiteaves, Cont. Canadian Pal., I, 1892, p. 291, pl. 37, figs. 9, 10.

Eunella sullivanti Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 290, fig. 210, pl. 80, figs. 23–26.

Loc. Columbus and Sandusky, Ohio; near Cayuga, Ontario, and Lakes Manitoba, and Winnipegosis, Canada.

GLASSIA Davidson. Genotype Atrypa obovata Sowerby.

Glassia Davidson, Geol. Mag., n. ser., VIII, 1881, p. 11;—Sup. British Devonian and Silurian Brach., Pal. Soc., 1882, p. 38.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 152, figs. 142–145;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 811.

Digitized by Google

Glassia romingeri Hall and Clarke. Trenton (Ord.).

Glassia romingeri Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 153, pl. 83, figs. 32–35.

Loc. Drift near Ann Arbor, Michigan.

Glassia schucherti Ulrich=Catazyga headi.

GLOSSINA Phillips. Genotype Lingula attenuata Sowerby.

Glossina Phillips, Mem. Geol. Survey Great Britain, II, Pt. II, 1848, p. 370.—Dall, Bull. U. S. Nat. Mus., 8, 1877, p. 29.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 15, 164;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 230.

Glossina acuminata Hall and Clarke=Lingulepis acuminata.

Glossina crassa (Hall). Trenton (Ord.).

Lingula crassa Hall, Pal. New York, I, 1847, p. 98, pl. 30, fig. 8.

Loc. Middleville and Lake Champlain, New York.

Glossina cyane (Billings). Calciferous (Ord.).

Lingula cyane Billings, Pal. Fossils, I, 1865, p. 216, fig. 200.

Loc. Near Portland Creek, Newfoundland.

Glossina deflecta Winchell and Schuchert. Trenton and Lorraine (Ord.).

Lingula (Glossina) deflecta Winchell and Schuchert, American Geol., IX, 1892, p. 284;—Minnesota Geol. Survey, III, 1893, p. 348, pl. 29, figs. 15–18.

Loc. Near Fountain and Spring Valley, Minnesota.

Glossina dubia (d'Orbigny). Ordovician.

Lingula dubia d'Orbigny, Voyage dans l'Amérique Méridionale, 1842, p. 29, pl. 2, fig. 7.

Loc. Tacopaya, Bolivia.

Glossina flabellula Hall and Clarke. Waverly (L. Carb.).

Lingula (Glossina) flabellula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 15, 172, pl. 1, figs. 33, 31.

Loc. Sciotoville, Ohio.

Glossina hurlbuti N. H. Winchell. Trenton (Ord.).

Lingula hurlbuti N. H. Winchell, Eighth Ann. Rep. Geol. Nat. Hist., Survey Minnesota, 1880, p. 62.

Lingula (Glossina) hurlbuti Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 347, pl. 29, figs. 13, 14.

Loc. Mantorville and near Spring Valley, Minnesota.

Glossina leana (Hall). Hamilton (Dev.).

Lingula leana Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 20;—Pal. New York, IV, 1867, p. 9, pl. 2, fig. 12.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 106, pl. 13, fig. 2.

Loc. Bristol, New York; Lone Mountain, Nevada.

Glossina nebraskaensis (Meek). Upper Carboniferous.

Lingula scotica var. nebraskensis Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 158, pl. 8, fig. 3.

Lingula nebraskensis Miller, N. American Geol. Pal., 1889, p. 350.

Loc. Nebraska City, Nebraska.

Glossina perovata (Hall). Clinton (Sil.).

Lingula perovata Hall, Pal. New York, II, 1852, p. 55, pl. 20, fig. 3.

Loc. Rochester, New York.

Digitized by Google

Glossina sedaliaensis (Miller). Chouteau (L. Carb.).

Lingula sedaliensis Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 308, pl. 9, fig. 2.

Loc. Sedalia, Missouri.

Obs. This species is probably the same as G. waverlyensis.

Glossina spatiosa (Hall). Lower Helderberg (Dev.).

Lingula spatiosa Hall, Pal. New York, III, 1859, p. 158, pl. 9, fig. 10.

Loc. Near Hudson, New York.

Glossina trentonensis (Conrad). Trenton and Utica (Ord.).

Lingula trentonensis Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 266, pl. 15, fig. 11.—Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 48.

Lingula attenuata? Hall (non Sowerby), Pal. New York, I, 1847, p. 94, pl. 30, fig. 1.

Lingula daphne Billings, Pal. Fossils, I, 1862, p. 50.

?Lingula attenuata A. Ulrich, N. Yahrb. f. Mineral, Beilageband, VIII, 1892, p. 7, pl. 1, fig. 3.

Loc. Glens Falls, Trenton Falls, Middleville, New York; Wisconsin; Montreal and Ottawa, Canada; ?near Vacas, Bolivia.

Glossina triangulata (Nettelroth). Hamilton (Dev.).

Lingula triangulata Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 34, pl. 26, fig. 1.

Loc. Falls of Ohio.

Glossina waverlyensis (Herrick). Waverly (L. Carb.).

Lingula scotica?? Meek, Pal. Ohio, II, 1875, p. 276, pl. 14, fig. 9.

Lingula waverlyensis Herrick, Bull. Denison Univ., IV, 1888, pp. 12, 18, pl. 3, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 9, pl. 4K, fig. 7.

Lingula (scotica var.) waverlyensis Herrick, Geol. Ohio, VII, 1895, pl. 22, fig. 1.

Loc. Berea and Newark, Ohio; Oil City, Pennsylvania.

Obs. See G. sedaliaensis (Miller).

Goniocœlia Hall=Pentagonia.

Goniocœlia uniangulata Hall=Pentagonia unisulcata.

Gotlandia Dall=Trimerella.

Gypidia Dalman=Conchidium.

Gypidia unguiformis Ulrich=Conchidium unguiformis.

GYPIDULA Hall. Genotype Pentamerus occidentalis Hall.

Gypidula Hall, Twentieth Rep. New York State Cab. Nat. Hist., 1867, p. 163;—Pal. New York, IV, 1867, pp. 373, 380.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 161.

Sieberella Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1311.

Gypidula and Sieberella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 245;—Thirteenth Ann. Rep. New York State Geol., 1895, pp. 845, 846.

Gypidula comis (Owen). Middle Devonian.

Atrypa comis Owen, Geol. Rep. Wisconsin, Iowa, Minnesota, 1852, p. 583, pl. 3A, fig. 4 (see specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17928).

Pentamerus (n. sp. ?) Owen, Ibidem, 1852, pl. 3A, fig. 11 (Ibidem, Cat., 17929).

Pentamerus occidentalis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 514, pl. 6, fig. 2 (non Pentamerus occidentalis Hall, 1852).

Pentamerus galeatiformis Meek and Worthen, Geol. Survey, Illinois, II, 1866, p. 325.

Gypidula occidentalis Hall, Pal. New York, IV, 1867, p. 380, pl. 58A, figs. 1–8.

Digitized by Google

Gypidula comis (Owen)—Continued.

Pentamerus comis Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 428, pl. 13, fig. 6.—Whiteaves, Cont. Canadian Pal., I, 1892, p. 290.

Pentamerus (Gypidula) comis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 159, pl. 3, figs. 4, 7; pl. 14, fig. 15; pl. 15, fig. 5.

Gypidula comis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 247, fig. 177; pl. 72, figs. 15–24.

Loc. Independence and Davenport, Iowa; Rock Island, Illinois; Eureka district, Nevada; lakes Manitoba and Winnipegosis, Canada.

Gypidula coppingeri (Etheridge). Silurian.

Pentamerus coppingeri Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 594, pl. 25, figs. 2, 3.

Loc. Offley Island, lat. 81° 16′.

Gypidula galeata (Dalman). Lower Helderberg and Middle Devonian.

Atrypa galeata Dalman, Kongl. Svenska, Vet.-Akad. Handl., för 1827, 1828, p. 46, pl. 5, fig. 4.—Troost, Sixth Geol. Rep. Tennessee, 1841, p. 15.—Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 117, fig. 1.—Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 39, pl. 14, fig. 4.

Pentamerus galeatus Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 105, figs. 1–3.—Rogers, Geol. Pennsylvania, II, Pt. II. 1858, p. 825, fig. 646.—Hall, Pal. New York, III, 1859, p. 257, pl. 46, fig. 1; pl. 47, fig. 1.—Billings, Geol. Canada, 1863, p. 957, fig. 454.

Pentamerus galeatus var. Whiteaves, Cont. to Canadian Pal., I, 1891, p. 234.

Sieberella galeatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 246, fig. 175; pl. 72, figs. 7–13.

Loc. Europe; Albany and Schoharie counties, New York; Cumberland, Maryland; Pennsylvania; St. Blandine, New Brunswick; Mackenzie River, Canada.

Gypidula globulosa (Nettelroth). Niagara (Sil.).

Pentamerus globulosus Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 54.

Loc. Louisville, Kentucky.

Gypidula knotti (Nettelroth). Niagara (Sil.).

Pentamerus knotti Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 56, pl. 32, figs. 9–12.

Loc. Louisville, Kentucky.

Gypidula lævivscula Hall. Middle Devonian.

Gypidula lævivscula Hall, Pal. New York, IV, 1867, p. 381, pl. 58, figs. 22, 23.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 248, pl. 72, figs. 25, 26.

Loc. Waterloo, Iowa.

Gypidula lotis (Walcott). Upper Devonian.

Pentamerus lotis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 161, pl. 3, fig. 9.

Gypidula lotis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 248.

Loc. White Pine mining district, Nevada.

Gypidula munda Calvin. Middle Devonian.

Gypidula munda Calvin, Bull. U. S. Geol. Geogr. Survey Terr., IV, 1878, p. 730.

Gypidula mundula Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 248.

Loc. Independence, Iowa.

Gypidula nucleus (Hall and Whitfield). ? Clinton (Sil.).

Pentamerus galeatus Hall and Whitfield, Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, pp. 197, 200a.

Pentamerus nucleus Hall and Whitfield, Twenty-seventh Rep. New York State Cab. Nat. Hist., 1875, pl. 9, figs. 30–32.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 59, pl. 27, figs. 25–27; pl. 33, figs. 27–33.

Digitized by Google

Gypidula nucleus (Hall and Whitfield)—Continued.

Sieberella nucleus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 247, pl. 72, figs. 1-3.

Loc. Louisville, Kentucky.

Gypidula occidentalis Hall=G. comis.

Gypidula pseudogaleata (Hall). Lower Helderberg (Dev.).

Pentamerus pseudogaleatus Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 106, figs. 1-6;—Pal. New York, III, 1859, p. 259, pl. 46, fig. 2.

Sieberella pseudogaleata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 242, pl. 72, fig. 14.

Loc. Schoharie and Carlisle, New York.

Gypidula rœmeri (Hall and Clarke). Silurian.

Pentamerus galeatus Roemer (not Dalman), Sil. Fauna west. Tennessee, 1860, p. 73, pl. 5, fig. 14.

Sieberella rœmeri Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 247, pl. 72, fig. 6.

Loc. Decatur County, Tennessee.

Gypidula romingeri Hall and Clarke. Hamilton (Dev.).

Gypidula romingeri Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 248, pl. 72, figs. 27-33.

Loc. Alpena, Michigan.

Gypidula subglobosa (Meek and Worthen). Hamilton (Dev.).

Pentamerus subglobosus Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 429, pl. 13, fig. 5.

Gypidula subglobosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 248.

Loc. Rock Island, Illinois.

Gypidula uniplicata (Nettelroth). Niagara (Sil.).

Pentamerus uniplicatus Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 63, pl. 33, figs. 25, 26.

Sieberella uniplicata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 247.

Loc. Louisville, Kentucky.

HARTTINA Hall and Clarke. Genotype Centronella anna Hartt.

Harttina Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 292;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 862.

Harttina coutinhoana (Derby). Upper Carboniferous.

Waldheimia coutinhoana Derby, Bull. Cornell Univ., I, 1874, p. 3, pl. 3, fig. 22; pl. 8, fig. 6; pl. 9, figs. 1, 2.

Harttina coutinhoana Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 292.

Loc. Bomjardim, Brazil.

Harttina anna (Hartt). Upper Carboniferous.

Centronella anna Hartt, Dawson's Acadian Geol., 3d ed., 1878, p. 300, fig. 99.

Harttina anna Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 292, figs. 211, 212; pl. 79, figs. 37-39.

Loc. Windsor, Nova Scotia.

Hallina Winchell and Schuchert=Zygospira.

HEBERTELLA Hall and Clarke. Genotype Orthis sinuata Hall.

Group of Orthis occidentalis Hall, Bull. Geol. Soc. America, I, 1889, p. 20.

Hebertella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 198, 222.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 432.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 266.

Digitized by Google

Hebertella battis (Billings). Calciferous (Ord.).

Orthis battis Billings, Pal. Fossils, I, 1865, p. 185.

Hebertella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Loc. Point Levis, Canada.

Hebertella bellirugosa (Conrad). Trenton (Ord.).

Orthis bellarugosa Conrad, Proc. Acad. Nat. Sci. Philadelphia, I, 1843, p. 333.—Hall, Pal. New York, I, 1847, p. 118, pl. 32, fig. 3.

Hebertella bellarugosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Orthis (Hebertella?) bellarugosa Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 434, pl. 33, figs. 1–4.

Loc. Mineral Point, Janesville, Neenah, etc., Wisconsin; Minneapolis, St. Paul, Cannon Falls, etc., Minnesota; Decorah and McGregor, Iowa; Curdsville, Kentucky; Rutherford County, Tennessee.

Hebertella borealis (Billings). Chazy-Trenton (Ord.).

Orthis borealis Billings, Canadian Nat. Geol., IV, 1859, p. 436, fig. 14;—Geol. Canada, 1863, p. 129, fig. 56; p. 167, fig. 148.—Meek, Pal. Ohio, I, 1873, p. 101, pl. 8, fig. 4.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 28.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 36, pl. 34, figs. 14–20.

Hebertella borealis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Orthis (Hebertella) borealis Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 433, fig. 33.

Loc. Caughnawaga, St. Genevieve, Isle Bizard, and Cornwall, Canada; Frankfort, Kentucky; Nashville, Tennessee; Cannon Falls, etc., Minnesota; Wisconsin (Whitfield).

Hebertella daytonensis (Foerste). Clinton (Sil.).

Orthis daytonensis Foerste, Bull. Denison Univ., I, 1885, p. 87, pl. 13, figs. 13, 20, 21.

Hebertella daytonensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Orthis (Hebertella) daytonensis Foerste, Geol. Ohio, VII, 1895, p. 575, pl. 25, figs. 13, 20, 21.

Loc. Dayton, Ohio.

Hebertella fausta (Foerste). Clinton (Sil.).

Orthis fausta Foerste, Bull. Denison Univ., I, 1885, p. 85, pl. 13, figs. 15, 16.

Hebertella fausta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Orthis (Hebertella) fausta and var. squamosa Foerste, Geol. Ohio, VII, 1895, pp. 573, 574, pl. 25, figs. 15a–15d, 16a, 16b; pl. 37A, figs. 19a, 19b.

Loc. Dayton, Ohio.

Hebertella imperator (Billings). Chazy (Ord.).

Orthis imperator Billings, Canadian Nat. Geol., IV, 1859, p. 435, figs. 11–13;—Geol. Canada, 1863, p. 129, fig. 55.

Hebertella imperator Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Loc. Hawkesbury and Cornwall, Canada.

Hebertella insculpta Hall. Lorraine (Ord.).

Orthis insculpta Hall, Pal. New York, I, 1847, p. 125, pl. 32, fig. 12.—Billings, Geol. Canada, 1863, p. 167, fig. 150.—Meek, Pal. Ohio, I, 1873, p. 99, pl. 9, fig. 1.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 40.

Orthis bellarugosa Hall (non Conrad), Second Ann. Rep. New York State Geol., 1883, pl. 35, fig. 22.

Hebertella insculpta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222, pl. 5A, fig. 13.

Digitized by Google

Hebertella insculpta Hall—Continued.

Orthis (Hebertella) insculpta Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 435.

Loc. Oxford, etc., Ohio; Richmond, Indiana; Wilmington, Illinois; Iron Ridge, Wisconsin; Lattners, Iowa.

Hebertella lonénsis (Walcott). Pogonip (Ord.).

Orthis lonensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 74, pl. 11, fig. 6.

Hebertella lonensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Loc. Eureka district, Nevada.

Hebertella maria (Billings). Lorraine (Ord.).

Orthis maria Billings, Pal. Fossils, I, 1862, p. 137, fig. 114.

Hebertella sinuata or maria? Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222, pl. 5A, figs. 9, 10.

Loc. Anticosti; Colby, Kentucky.

Hebertella occidentalis Hall. Lorraine (Ord.).

Orthis occidentalis Hall, Pal. New York, I, 1847, p. 127, pl. 32A, fig. 2; pl. 32B, fig. 1;—Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 72.—Billings, Geol. Canada, 1863, p. 210, fig. 210.—Meek, Pal. Ohio, I, 1873, p. 96, pl. 9, fig. 3.—White, Wheeler's Expl. Survey west 100th Merid., IV, 1875, p. 70, pl. 4, fig. 11.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 34.—White, Second Ann. Rep. Indiana Bureau Statistics and Geol., 1880, p. 485, pl. 2, figs. 10–12;—Tenth Rep. State Geol. Indiana, 1881, p. 117, pl. 2, figs. 10–12.—Whitfield, Geol. Wisconsin, IV, 1882, p. 260, pl. 12, figs. 17, 18.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 34, figs. 31–34; pl. 35, figs. 16–21.

Orthis subjugata Hall, Pal. New York, I, 1847, p. 129, pl. 32C, fig. 1.

Orthis subjugata(?) Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 2B, figs. 4, 5 (see specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17885).

Hebertella occidentalis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222, pl. 5A, figs. 11, 12.

Loc. Cincinnati, Oxford, etc., Ohio; Richmond, Indiana; Savanna, Illinois; Cape Girardeau, Missouri; Delafield, Wisconsin; Silver City, New Mexico.

Hebertella occidentalis sinuata Hall. Lorraine (Ord.).

Orthis sinuata Hall, Pal. New York, I, 1847, p. 128, pl. 32B, fig. 2.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 36.—Shaler, Fossil Brachiopoda Ohio Valley, 1887, pl. 8.

Orthis occidentalis var. sinuata Meek, Pal. Ohio, I, 1873, p. 98.

Hebertella sinuata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222, pl. 5A, figs. 1–8.

Loc. Cincinnati, Ohio.

Hebertella scovilli (Miller). Lorraine (Ord.).

Orthis scovilli Miller, Jour. Cincinnati Soc. Nat. Hist., V, 1882, p. 40, pl. 1, fig. 5.

Hebertella scovilli Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 222.

Loc. Lebanon, Ohio.

Hemipronites americanus Whitfield=Clitambonites diversus.

Hemipronites apicalis Whitfield=Polytœchia apicalis.

Hemipronites crassus McChesney=Derbya crassa.

Hemipronites crenistria White (non Meek or Phillips)=Derbya crassa.

Hemipronites crenistria Meek, and Herrick=Orthothetes crenistria.

Hemipronites propinquus Meek and Worthen=Orthothetes subplanus.

HEMITHYRIS d'Orbigny. Genotype Rhynchonella psittacea Gmel.

Hemithyris d'Orbigny, Ann. Sci. Nat., VIII, 1850, p. 246; XIII, 1850, p. 322.

Digitized by Google

Hemithyris psittacea (Chemnitz). Pliocene and Recent.

Anomia rostrum psittacea Chemnitz, Neues syst. Conch.-Cab., VIII, 1785, pl. 78, fig. 713.

Rhynchonella psittacea Davidson, Trans. Linnæan Soc. London, IV, 1887, p. 163, pl. 24, figs. 1–11.

Loc. Fossil. Gulf of St. Lawrence, Canada.

HETERORTHIS Hall and Clarke. Genotype Orthis clytie Hall.

Heterorthis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 207, 223;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 268.

Heterorthis clytie Hall. Trenton (Ord.).

Orthis clytie Hall, Fourteenth Rep New York State Cab. Nat. Hist., 1861, p. 90;—Fifteenth Rep., Ibidem, 1862, pl. 2, figs. 4, 5.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 34.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 75, pl. 1, figs. 18, 19.

Heterorthis clytie Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 202, 223, pl. 5B, figs 20–24.

Loc. Frankfort and Paris, Kentucky.

HINDELLA Davidson. Genotype Athyris umbonata Billings.

Hindella Davidson, Suppl. British Sil. Brach., Pal. Soc., 1882, p. 130.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 63, figs. 46–51;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 769.

Hindella prinstana (Billings). Anticosti (Sil.).

Athyris prinstana Billings, Pal. Fossils, I, 1862, p. 145, fig. 122.

Meristella prinstana Miller, N. American Geol. Pal., 1889, p. 354.

Hindella prinstana Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 64, pl. 41, fig. 28; pl. 49, fig. 1.

Loc. Anticosti.

Hindella umbonata (Billings). Anticosti (Sil.).

Athyris umbonata Billings, Pal. Fossils, I, 1862, p. 144, fig. 121;—Geol. Canada, 1863, p. 317, fig. 331.

Hindella umbonata Davidson, Suppl. British Sil. Brach., Pal. Soc., 1882, p. 130, fig. in text.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 64, figs. 46–51; pl. 41, figs. 26, 27, 29, 30.

Meristella umbonata Foerste, Bull. Denison Univ., I, 1885, p. 88, pl. 13, fig. 2;—Geol. Ohio, VII, 1895, p. 590, pl. 25, fig. 2.

Loc. Anticosti; Dayton, Ohio (Foerste).

HIPPARIONYX Vanuxem.

Genotype Hipparionyx proximus Vanuxem.

Hipparionyx Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 124, fig. 4.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 257;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 284.

Hipparionyx consimilaris Vanuxem=Atrypa reticularis.

Hipparionyx proximus Vanuxem. Oriskany (Dev.).

Hipparionyx proximus Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 124, fig. 29, No. 4.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 257, pl. 9, figs. 33–36; pl. 15A, figs. 9–11.

Atrypa unguiformis (Conrad) Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 149, fig. 4.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 826, fig. 651

Orthis conradi Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 37, pl. 15, fig. 4.

Orthis unguiformis Castelnau, Ibidem, 1843, p. 37, pl. 15, fig. 3.—Emmons, Manual Geol., 1860, p. 129, fig. 115.

Digitized by Google

Hipparionyx proximus Vanuxem—Continued.

Orthis hipparionyx Hall, Pal. New York, III, 1859, p. 407, pl. 89, figs. 1–4; pl. 90, figs. 1–7; pl. 91, figs. 4, 5; pl. 94, fig. 4.

Strophodonta intermedia Hall, Pal. New York, III, 1859, p. 482, pl. 95A, figs. 13, 14.

Streptorhynchus hipparionyx Hall, Second Ann. Rep. New York State Geol., 1883, pl. 39, figs. 33–36.

Loc. Schoharie and Albany counties, New York; Frankstown, Pennsylvania; Cumberland, Maryland; Cayuga, Ontario.

Obs. This species does not occur in Germany according to Kayser.

HOMŒOSPIRA Hall and Clarke. Genotype Rhynchospira evax Hall.

Homœospira Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 112;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 792.

Homœospira apriniformis Hall. Niagara (Sil.).

Atrypa aprinis Hall (non de Verneuil), Pal. New York, II, 1852, p. 280, pl. 57, fig. 7.

Rhynchospira? aprinis Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 77.

Rhynchospira apriniformis Hall, Pal. New York, III, 1859, p. 485.

Rhynchonella aprinis Miller, N. American Geol. Pal., 1889, p. 367.

Homœospira apriniformis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 111, pl. 83, figs. 24, 25.

Loc. Lockport, New York.

Homœospira evax Hall. Niagara (Sil.).

Rhynchospira evax Hall, Trans. Albany Institute, IV, 1863, p. 213.

Retzia evax Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 160, pl. 25, figs. 13–21;—Eleventh Rep. State Geol. Indiana, 1882, p. 302, pl. 25, figs. 13–21.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 55, pl. 5, figs. 1–9.

Homœospira evax Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 112, pl. 50, figs. 15–20 (?32–35).

Loc. Waldron, Indiana; ?Perry County, Tennessee.

Homœospira sobrina (Beecher and Clarke). Niagara (Sil.).

Retzia sobrina Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 61, pl. 5, figs. 10–16.

Homœospira sobrina Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 112, pl. 50, figs. 26–28.

Loc. Waldron, Indiana.

HUSTEDIA Hall and Clarke. Genotype Terebratula mormoni Marcou.

Hustedia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 120;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 797.

Hustedia(?) meekana (Shumard). Upper Carboniferous.

Retzia(?) meekana Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 295, pl. 11, fig. 7.

Loc. Guadalupe Mountains, New Mexico.

Hustedia mormoni (Marcou). Upper Carboniferous.

Terebratula mormoni Marcou, Geol. N. America, February, 1858, p. 51, pl. 6, fig. 11;—Trans. St. Louis Acad. Sci., III, 1875, p. 252.

Retzia punctulifera Shumard, Trans. St. Louis Acad. Sci., I, June, 1858, p. 220.—McChesney, Trans. Chicago Acad. Sci., 1, 1868, p. 32, pl. 1, fig. 1.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 181, pl. 1, fig. 13; pl. 5, fig. 7.

Digitized by Google

Hustedia mormoni (Marcou)—Continued.

Retzia mormoni Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p. 27.—Geinitz, Carb. u. Dyas Nebraska, 1866, p. 39, pl. 3, fig. 6.—White, Wheeler's Expl. Survey west 100th Merid., IV, 1875, p. 141, pl. 10, fig. 7;—Thirteenth Rep. State Geol. Indiana, 1884, p. 136, pl. 35, figs. 10–12.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 231;—Geol. Survey Missouri, V, 1895, p. 95, pl. 41, fig. 2.

Retzia subglobosa McChesney, Descriptions New Pal. Foss., 1860, p. 45;—Ibidem, 1865, pl. 1, fig. 1.

Retzia compressa Meek, Geol. Survey California, I, 1864, p. 14, pl. 2, fig. 7.—Kayser, Richthofens China, IV, 1883, p. 176, pl. 22, figs. 1–4.

Enmetria punctulifera Derby, Bull. Cornell Univ., I, 1874, p. 4, pl. 8, figs. 4, 5, 7, 8, 10; pl. 9, fig. 3.

Retzia radialis Walcott (non Phillips), Mon. U. S. Geol. Survey, VIII, 1884, p. 220, pl. 7, figs. 5d–5h.—Smith, Proc. American Phil. Soc., XXXV, 1897, p. 31.

Hustedia mormoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 120, fig. 106; pl. 51, figs. 1–9.

Loc. Salt Lake City, Utah; Santa Fe, New Mexico; Nevada; Shasta County, California; Nebraska; Kansas; Arkansas; Missouri; Iowa; Illinois; Indiana; Bomjardim and Itaituba, Brazil; Lo Ping, China.

Hustedia(?) papillata (Shumard). Upper Carboniferous.

Retzia papillata Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 294, pl. 11, fig. 9.

Loc. Guadalupe Mountains, New Mexico.

Obs. Compare with H. mormoni.

Hustedia(?) triangularis (Miller). Chouteau (L. Carb.).

Retzia triangularis Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 315, pl. 9, figs. 25, 26.

Loc. Sedalia, Missouri.

HYATTELLA Hall and Clarke. Genotype Atrypa congesta Conrad.

Hyattella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 61, fig. 45;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 767.

Hyattella congesta (Conrad). Clinton (Sil.).

Atrypa congesta Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 265, pl. 16, fig. 18.—Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 71, fig. 2;—Pal. New York, II, 1852, p. 67, pl. 23, fig. 1.—Billings, Canadian Nat. Geol., I, 1856, p. 136, pl. 2, fig. 4.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 823, fig. 632.

Atrypa quadricostata Hall, Pal. New York, II, 1852, p. 68, pl. 23, fig. 2.

Triplesia? congesta Hall, Twelfth Rep. New York State Cab. Nat. Hist., 1859, p. 77.

Triplesia? quadricostata Hall, Ibidem, 1859, p. 78.

Rhynchonella quadricostata Miller, N. American Geol. Pal., 1889, p. 369.

Camerella congesta Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 48.

Hyattella congesta Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 61, fig. 45; pl. 40, figs. 23–28; pl. 81, figs. 26–28.

Loc. Rochester, Reynales Basin, etc., New York; Flamborough Head, Ontario; Pennsylvania; Louisville, Kentucky.

Hyattella junia (Billings). Anticosti (Sil.).

Athyris junia Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 46.

Hyattella junia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 62, pl. 40, figs. 29–31.

Loc. Anticosti.

Digitized by Google

HYPOTHYRIS King. Genotype Atrypa cuboides Sowerby.

Hypothyris King (non Phillips), Ann. Mag. Nat. Hist., XVIII, 1846, p. 28;—Mon. Permian Foss., Pal. Soc., 1850, pp. 81, 100, 111.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 200;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 828.

Hypothyris castanea (Meek). Middle Devonian.

Rhynchonella castanea Meek, Trans. Chicago Acad. Sci., I, 1868, p. 93, pl. 13, fig. 9.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 153, pl. 15, figs. 1, 4.—Whiteaves, Cont. to Canadian Pal., I, 1891, p. 232.

Liorhynchus castaneus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 59, figs. 28, 29.

Loc. Lockhart and Mackenzie River, Canada; Eureka district, Nevada.

Hypothyris cuboides (Sowerby). Tully (Dev.).

Atrypa cuboides Sowerby, Trans. Geological Soc., 2d ser., V, 1840, pl. 6, fig. 24.—Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 163, fig. 1.—Hall, Ibidem, Rep. Fourth Dist., 1843, pp. 215, 216, fig. 1.

Rhynchonella venustula Hall, Pal. New York, IV, 1867, p. 346, pl. 54A, figs. 24–43.—Williams, Bull. Geol. Soc. America, I, 1890, p. 493, pl. 13, figs. 4, 8, 14, 23, 24, 27, 29, 31–34.

Hypothyris cuboides and venustula Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 200, pl. 60, figs. 49–55.

Loc. Europe; Tully, Ovid, Penn Yan, etc., New York.

Hypothyris emmonsi (Hall and Whitfield). Middle Devonian.

Rhynchonella emmonsi Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 247, pl. 3, figs. 4–8.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 157.

Rhynchonella intermedia Barris, Proc. Davenport Acad. Nat. Sci., II, 1878, p. 285, pl. 11, figs. 5, 6.

Rhynchonella cuboides Whiteaves, Cont. to Canadian Pal., I, 1891, p. 231.

Hypothyris emmonsi and intermedia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 200.

Loc. White Pine district, Nevada; Davenport, Iowa; Hay and Peace rivers, Canada.

IPHIDEA Billings. Genotype Iphidea bella Billings.

Iphidea Billings, Canadian Nat. Geol., n. ser., VI, 1872, p. 477;—Pal. Fossils, II, 1874, p. 76.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 100.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 97, 166;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 249.—Walcott, Proc. U. S. National Mus., XIX, 1897, p. 707.

Micromitra Meek, Sixth Ann. Rep. U. S. Geol. Survey Terr., 1873, p. 479.

Kutorgina (pars) Dall, Bull. U. S. National Mus., 8, 1877, p. 40.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 101.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 90.

Paterina Beecher, American Jour. Science, 3d ser., XLI, 1891, p. 345.—Hall and Clarke, Eleventh Rep. N. Y. State Geologist, 1894, p. 247.

Iphidea alabamaensis Walcott. Middle Cambrian.

Iphidea alabamaensis Walcott, Proc. U. S. National Mus., XIX, 1897, p. 713, pl. 59, figs. 5, 5a.

Loc. Coosa Valley, Cherokee County, Alabama; near Rogersville, Tennessee.

Iphidea bella Billings. Lower Cambrian.

Iphidea bella Billings, Canadian Nat. Geol., n. ser., VI, 1872, p. 447, fig. 13;—Pal. Fossils, II, 1874, p. 76, fig. 44.—Walcott, Bull, U. S. Geol. Survey, 30, 1886,

Digitized by Google

Iphidea bella Billings—Continued.

p. 100, pl. 7, fig. 4;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 608, pl. 67, fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 98, fig. 54, pl. 4, figs. 8, 9.

Loc. Trois Pistoles, below Quebec, Canada; Anse au Loup, Labrador.

Iphidea crenistria Walcott. Middle Cambrian.

Iphidea crenistria Walcott, Proc. U. S. National Mus., XIX, 1897, p. 713, pl. 59, figs. 4–4b.

Loc. Grand Canyon of the Colorado.

Iphidea labradorica (Billings). Lower Cambrian.

Obolus labradoricus Billings, Geol. Vermont, II, 1861, p. 946, fig. 345;—Pal. Fossils, I, 1861, p. 6, fig. 6;—Geol. of Canada, 1863, p. 284, fig. 291.

Kutorgina labradorica Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 104, pl. 9, fig. 2;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 609, pl. 69, fig. 3.

Paterina labradorica Beecher, American Jour. Sci., 3d ser., XLI, 1891, pp. 345, 356, pl. 17, figs. 1, 2.

Loc. Anse au Loup, Straits of Belle Isle, Labrador; Conception Bay, Newfoundland.

Iphidea labradorica swantonensis Walcott. Lower Cambrian.

Kutorgina labradorica var. swantonensis Walcott, Proc. U. S. Nat. Mus., XII, 1889, p. 36;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 609, pl. 69, fig. 2.

Loc. East of Swanton and Highgate Springs, Vermont.

Iphidea logani Walcott. Middle Cambrian.

Iphidea logani Walcott, Proc. U. S. National Mus., XIX, 1897, p. 711, pl. 59, figs. 2–2b.

Loc. Trois Pistoles, Quebec, Canada.

Iphidea ornatella Hall and Clarke=I. superba.

Iphidea pannulus (White). Lower and Middle Cambrian.

Trematis pannulus White, Wheeler's Expl. Survey west 100th Merid., Prel. Rep., 1874, p. 6.

Trematis? pannulus White, Ibidem, Final Rep., IV, 1875, p. 36, pl. 1, fig. 4.

Kutorgina pannula Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 105, pl. 7, fig. 3; pl. 8, fig. 2;—American Jour. Sci., 3d ser., XXXIV, 1887, p. 190, pl. 1, fig. 14;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 609, pl. 69, fig. 5.

Loc. Pioche, Nevada; Wasatch Mountains, Utah; Mount Stephan and Castle Mountain, British Columbia; Washington County, New York; Island of Orleans in the Sillery conglomerate.

Iphidea pealei Walcott. Middle Cambrian.

Iphidea pealei Walcott, Proc. U. S. National Mus., XIX, 1897, p. 712, pl. 59, figs. 3–3c.

Loc. Near Hillsdale, Montana.

Iphidea prospectensis Walcott. Lower Cambrian.

Kutorgina prospectensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 19, pl. 9, fig. 1;—Bull. U. S. Geol. Survey, 30, 1886, p. 106, pl. 9, fig. 3;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 610, pl. 69, fig. 4.

Loc. Eureka district, Nevada.

Iphidea sculptilis Meek. Upper Cambrian.

Iphidea (??) sculptilis Meek, Sixth Ann. Rep. U. S. Geol. Survey Territories, 1873, p. 479.

Micromitra sculptilis Meek, Ibidem, 1873, p. 479.

Kutorgina minutissima Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 207, pl. 1, figs. 11, 12.

Digitized by Google

Iphidea sculptilis Meek—Continued.

Kutorgina sculptilis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 20, pl. 1, fig. 7; pl. 9, fig. 7.

Loc. Gallatin City, Montana; Eureka district, Nevada.

Obs. The ventral pedicle foramen in this species, the genotype of Micromitra, is partially closed posteriorly, but otherwise does not seem to differ generically from Iphidea.

Iphidea stissingensis (Dwight). Middle Cambrian.

Kutorgina stissingensis Dwight, American Jour. Sci., 3d ser., XXXVIII, 1889, p. 145, pl. 6, figs. 5–8;—Trans. Vassar Brothers' Inst., V, 1891, p. 105, pl. 1, figs. 5–8.

Loc. Stissing Mountain, Duchess County, New York.

Iphidea superba Walcott. Middle Cambrian.

Iphidea cnf. † ornatella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4, figs. 6, 7.

Iphidea superba Walcott, Proc. U. S. National Mus., XIX, 1897, p. 711, pl. 59, figs. 1–1c.

Loc. Grand Canyon of the Colorado.

Isogramma Meek and Worthen=Aulacorhynchus.

Isogramma millipunctata Meek and Worthen=Aulacorhynchus millipunctatum.

KINGENA Davidson. Genotype Terebratula lima Defrance.

Kingena Davidson, Mon. British Cret. Brach., Pal. Soc., I, 1853, p. 42.

Kingena leonensis (Conrad). Washita (Lower Cret.).

Terebratula leonensis Conrad, Emory's Rep. U. S. and Mexican Bound. Survey, I, 1857, p. 164, pl. 21, fig. 2.—Gabb, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 18.

Loc. Leon Springs, Texas; also Denison, Texas (Hill).

Kingena wacoensis (Roemer). Washita (Lower Cret.).

Terebratula sp. undet. Roemer, Texas, 1849, p. 408.

Terebratula wacoensis Roemer, Kreidebildung von Texas, 1852, p. 81, pl. 6, fig. 2.—Gabb, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 18.

Terebratula choctawensis Shumard, Marcy's Rep. Red River Louisiana, 1854, p. 195, pl. 2, fig. 3.—Gabb, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 19.

†Terebratula wacoensis Whiteaves, Mesozoic Foss., Geol. Surv. Canada, I, 1879, p. 177.

Loc. Near New Braunfels, Texas; Trent River, Vancouver Island. "I have traced its continuity from the Red River to the Rio Grande" (Hill).

Obs. Gabb is correct in regarding T. choctawensis as a synonym for T. wacoensis. "The Vancouver specimens are doubtful" (Stanton).

Klitambonites Pander=Clitambonites.

Koninckiana americana Swallow=Productus swallovi.

KUTORGINA Billings. Genotype Obolella cingulata Billings.

Kutorgina Billings (partim), Geol. Vermont, II, 1861, p. 948, figs. 347–349.—Billings (partim), Pal. Fossils, I, 1861, p. 9, figs. 8–10.—Dall, Bull. U. S. Nat. Mus., 8, 1877, p. 40.—Walcott (partim), Bull. U. S. Geol. Survey, 30, 1886, p. 101.—Beecher, American Jour. Sci., 3d ser., XLI, 1891, p. 345.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 90, 166, 183;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 247.

Digitized by Google

Kutorgina cingulata Billings. **Lower Cambrian.**

Obolella (Kutorgina) cingulata Billings, Geol. Vermont, II, 1861, p. 948, figs. 347-349;—Pal. Fossils, I, 1861, p. 8, figs. 8-10.

Obolella cingulata Billings, Geol. Canada, 1863, p. 284, fig. 287.

Kutorgina cingulata Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 102, pl. 9, fig. 1.—Beecher, American Jour. Sci., 3d ser., XLI, 1891, p. 345.—Walcott, Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 609, pl. 69, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 92, figs. 47-49; pl. 4, figs. 10-17.

Loc. Anse au Loup, Labrador; Swanton and Georgia, Vermont; Malvern Hills, England; Island of Bornholm, Sweden.

Kutorgina labradorica Walcott=Iphidea labradorica.

Kutorgina labradorica var. swantonensis Walcott=Iphidea labradorica swantonensis.

Kutorgina latourensis Matthew=Billingsella latourensis.

Kutorgina minutissima Hall and Whitfield=Iphidea sculptilis.

Kutorgina pannula White=Iphidea pannulus.

Kutorgina prospectensis Walcott=Iphidea prospectensis.

?Kutorgina pterineoides Matthew. **Middle Cambrian.**

Kutorgina ? pterineoides Matthew, Trans. Royal Soc. Canada, III, 1886, p. 43, pl. 5, fig. 19.

Loc. Hanford Brook and St. Martins, New Brunswick.

Obs. It is not certain that this species is a brachiopod. May be the operculum of a pteropod.

Kutorgina sculptilis Walcott=Iphidea sculptilis.

Kutorgina stissingensis Dwight=Iphidea stissingensis.

Kutorgina whitfieldi Walcott=Billingsella whitfieldi.

LEIORHYNCHUS Hall. Genotype Orthis quadricostata Vanuxem.

Leiorhynchus Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 75;—Twentieth Rep. Ibidem, 1867, p. 272;—Pal. New York, IV, 1867, p. 355.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 411.

Liorhynchus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 193;—Thirteenth Ann. Rep. New York State Geologist, 1895, p. 827.

Obs. A subgenus of Camarotœchia, differing only in exterior ornamentation.

Leiorhynchus boonense (Shumard). Burlington (L. Carb.).

Rhynchonella boonensis Shumard, Geol. Rep. Missouri, 1855, p. 205, pl. C, fig. 6.—Keyes, Geol. Survey Missouri, V, 1895, p. 101.

Liorhynchus boonensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194, pl. 60, fig. 35.

Loc. Columbia, Boone County, and Cooper County, Missouri.

Leiorhynchus dubium Hall. **Marcellus (Dev.).**

Leiorhynchus dubius Hall, Pal. New York, IV, 1867, p. 364, pl. 56, figs. 22-25.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 59, figs. 6, 7.

Rhynchonella dubia Tschernyschew, Mém. Comité Géologique de St. Petersburg, III, 3, 1887, p. 90, pl. 14, fig. 7.

Loc. New York; Urals of Russia.

Leiorhynchus globuliforme (Vanuxem). **Chemung (Dev.).**

Atrypa globuliformis Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 182, fig. 2.

Leiorhynchus globuliformis Hall, Pal. New York, IV, 1867, p. 364, pl. 57, figs. 26-29.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194, pl. 59, figs. 23-27.

Loc. Otsego County, New York.

Digitized by Google

Leiorhynchus greeneanum (Ulrich). Waverly (L. Carb.).

Rhynchonella greenana Ulrich, Cont. American Pal., I, 1886, p. 26, pl. 3, fig. 1.

Liorhynchus greenianus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194.

Pugnax greenianus Hall and Clarke, Ibidem, 1895, pl. 60, figs. 36–38.

Loc. Near New Albany, Indiana.

Leiorhynchus (?) hecate Clarke. Genesee (Dev.).

Leiorhynchus(?) hecate Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 31, pl. 3, fig. 4.

Loc. Ontario County, New York.

Obs. Probably the same as Spirifer pluto Clarke.

Leiorhynchus iris Hall. Chemung (Dev.).

Leiorhynchus iris Hall, Pal. New York, IV, 1867, p. 360, pl. 56, figs. 41–43.

Loc. Rockford, Iowa.

Leiorhynchus kelloggi Hall. Hamilton (Dev.).

Leiorhynchus kelloggi Hall, Pal. New York, IV, 1867, p. 361, pl. 57, figs. 1–12.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194, pl. 59, figs. 18–20, 32, 33.

Leiorhynchus kelloggi? Whitfield, Geol. Wisconsin, IV, 1882, p. 334, pl. 26, fig. 9.

Rhynchonella kelloggi Tschernyschew, Mém. Comité Géologique de St. Petersburg, III, 3, 1887, p. 91, pl. 14, fig. 14.

Loc. Ohio; New York; Milwaukee, Wisconsin; Urals of Russia.

Leiorhynchus laura (Billings). Marcellus-Hamilton (Dev.).

Rhynchonella? laura Billings, Canadian Jour., V, May, 1860, p. 273, figs. 26–28;—Geol. Canada, 1863, p. 384, fig. 418.

Leiorhynchus multicosta Hall, Thirteenth Rep. New York State Cab. Nat. Hist., December, 1860, p. 85, figs. 14, 15, on p. 94;—Pal. New York, IV, 1867, p. 358, pl. 56, figs. 26–40.

Leiorhynchus laura Billings, Canadian Nat. Geol., n. ser., VII, 1874, p. 240.

Rhynchonella (Leiorhynchus) laura Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 159.

? Rhynchonella multicosta Tschernyschew, Devon. im Donetz Becken, 1886, pl. 15, figs. 1–3;—Mém. Comité Géologique de St. Petersburg, III, 3, 1887, p. 92.

Liorhynchus multicosta and laura Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194, pl. 59, figs. 8–10, 13–17.

Loc. Thedford and Bosanquet, Ontario; New York; Eureka district, Nevada; ? Russia.

Leiorhynchus lesleyi Hall and Clarke. Upper Devonian.

Liorhynchus lesleyi Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 368, pl. 59, figs. 34–36.

Loc. "Pennsylvania."

Leiorhynchus limitare (Vanuxem). Marcellus (Dev.).

Orthis limitaris Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 146, fig. 3.

Atrypa limitaris Hall, Ibidem, Rep. Fourth Dist., 1843, p. 182, fig. 11.

Leiorhynchus limitaris Hall, Thirteenth Rep. New York State Cab. Nat Hist., 1860, p. 85;—Pal. New York, IV, 1867, p. 356, pl. 56, figs. 6–21.—Whitfield, Annals New York Acad. Sci., V, 1891, p. 550, pl. 11, fig. 11;—Geol. Ohio, VII, 1895, p. 444, pl. 7, fig. 11.

Rhynchonella limitaris Tschernyschew, Mémoires du Comité Géologique de St. Petersburg, 1887, III, 3, pl. 14, fig. 5.

Liorhynchus limitaris Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194, pl. 59, figs. 12, 35.

Loc. Schoharie, Marcellus, Avon, etc., New York; Delaware County, Ohio (Whitfield); Urals of Russia.

Digitized by Google

Leiorhynchus mesicostale Hall. Portage-Chemung (Dev.).

Atrypa mesacostalis Hall, Geol. New York; Rep. Fourth Dist., 1843, Tables Organic Remains, 64, fig. 1.

Leiorhynchus mesacostalis Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 86, fig. 1;—Pal. New York, IV, 1867, p. 362, pl. 67, figs. 18-25.—Kindle, Bull. American Pal., 6, 1896, p. 37.

Rhynchonella mesacostalis Tschernyschew, Mémoires du Comité Géologique de St. Petersburg, 1887, p. 91, pl. 14, figs. 3, 4.

Liorhynchus mesacostalis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194, pl. 59, figs. 11, 12.

Loc. Ithaca, Elmira, Bath, etc., New York; Urals of Russia.

Leiorhynchus multicosta Hall=L. laura.

Leiorhynchus mysia Hall. Marcellus (Dev.).

Leiorhynchus mysia Hall, Pal. New York, IV, 1867, p. 357, pl. 56, figs. 1-5.

Loc. Schoharie, New York.

Leiorhynchus nevadaense Walcott. Middle Devonian.

Rhynchonella (Leiorhynchus) nevadensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 157, pl. 14, fig. 9.

Loc. Eureka district, Nevada.

Leiorhynchus newberryi Hall. Waverly (L. Carb.).

Leiorhynchus newberryi Hall, Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 240, pl. 11, figs. 25-27.

Liorhynchus newberryi Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194, pl. 59, figs. 37, 38.

Loc. Kelloggsville, Ashtabula County, Ohio.

Leiorhynchus quadricostatum (Vanuxem). Genesee (Dev.).

Orthis quadricostata Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 168, fig. 2.

Atrypa (Orthis) quadricostata Hall, Ibidem, Rep. Fourth Dist., 1843, p. 223, fig. 2.

Leiorhynchus quadricostata Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 86;—Pal. New York, IV, 1867, p. 357, pl. 56, figs. 44-49.—Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 24.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 71.

Leiorhynchus quadricostata? Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 79, pl. 3, fig. 9.

Liorhynchus quadricostatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 193, pl. 59, figs. 21, 22.

Loc. Ithaca, Seneca Lake, Cayuga Lake, New York; Falls of Ohio; White Pine district, Nevada.

Leiorhynchus robustum Hall and Clarke. Chemung (Dev.).

Liorhynchus robustus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pl. 59, figs. 30, 31.

Loc. Steuben County, New York.

Leiorhynchus sesquiplicatum A. Winchell. Hamilton (Dev.).

Leiorhynchus sesquiplicatus A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 93.

Loc. Grand Traverse district, Michigan.

Leiorhynchus sinuatum Hall. Chemung (Dev.).

Leiorhynchus sinuatus Hall, Pal. New York, IV, 1867, p. 362, pl. 57, figs. 13-17.

Rhynchonella (Leiorhynchus) sinuatus Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 158, pl. 14, fig. 5.

Liorhynchus sinuatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 194.

Loc. Ithaca and Chemung Narrows, New York; Eureka district, Nevada.

Digitized by Google

LEPTÆNA Dalman.

Genotype Productus rugosa Hisinger=Conchita rhomboidalis Wilckens.

Leptæna Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, pp. 93, 94.—King, Mon. Permian Foss., Pal. Soc., 1850, p. 104.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 276.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 409.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 277.

Leptagonia McCoy, Carb. Foss. Ireland, 1844, p. 116.

Plectambonites Œhlert, Fischer's Manuel Conchyliologie, 1887, p. 1283.

Leptæna alternata Conrad=Rafinesquina alternata.

Leptæna alternistriata Hall=Rafinesquina alternata alternistriata.

Leptæna barabuensis Whitfield=Syntrophia barabuensis.

Leptæna bipartita Hall=Strophomena bipartita.

Leptæna camerata Hall=Rafinesquina camerata.

Leptæna charlottæ Winchell and Schuchert. Trenton (Ord.).

Leptæna charlottæ Winchell and Schuchert, American Geol., IX, April 1, 1892, p. 288;—Minnesota Geol. Survey, III, 1893, p. 410, pl. 32, figs. 1–5.

Strophomena halli Sardeson, Bull. Minnesota Acad. Nat. Sci., III, April 9, 1892, p. 334, pl. 4, figs. 36–38.

Loc. Minneapolis and St. Paul, Minnesota.

Leptæna concava Hall=Leptænisca concava.

Leptæna corrugata Hall=Strophomena corrugata.

Leptæna decipiens Billings=Leptella decipiens.

Leptæna deflecta Hall=Dinorthis deflecta.

Leptæna deltoidea=Rafinesquina deltoidea and R. minnesotaensis.

Leptæna depressa Hall=L. rhomboidalis.

Leptæna fasciata Hall=Rafinesquina fasciata.

Leptæna incrassata Hall=Rafinesquina incrassata.

Leptæna indenta Conrad=Stropheodonta indenta.

Leptæna julia Shaler=Strophomena julia.

Leptæna laticosta de Verneuil=Tropidoleptus carinatus.

Leptæna melita Hall and Whitfield=Dalmanella melita.

Leptæna mesacosta Shumard=Rafinesquina mesicosta.

Leptæna minnesotensis Sardeson=Plectambonites sericeus.

Leptæna nucleata Hall=Anoplia nucleata.

Leptæna obscura Hall=Rafinesquina obscura.

Leptæna orthididea Hall=Strophonella orthididea.

Leptæna patenta Hall=Strophonella patenta.

Leptæna planoconvexa Hall=Strophomena planiconvexa.

Leptæna planumbona Hall=Strophomena rugosa.

Leptæna plicatella Ulrich=Plectambonites plicatellus.

Leptæna plicifera Hall=Dalmanella? plicifera.

Leptæna præcosis Sardeson=Plectambonites sericeus.

Leptæna profunda Hall=Stropheodonta profunda.

Leptæna prolongata Foerste=Plectambonites transversalis prolongatus.

Leptæna punctulifera Conrad=Strophonella punctulifera.

Digitized by Google

Leptæna quadrilatera Shaler=L. rhomboidalis.

Leptæna recedens Sardeson=Plectambonites sericeus.

Leptæna recta Hall=Dinorthis deflecta.

Leptæna rhomboidalis (Wilckens). Trenton-Waverly (Ord.-L. Carb.).

Conchita rhomboidalis Wilckens, Nachrict von selten Versteinerungen, 1769, p. 77, pl. 8, figs. 43, 44.

Strophomena undulosa Conrad, Fifth Ann. Rep. Geol. Survey New York, 1841, p. 54.

Strophomena depressa Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 79, fig. 5.—Hall, Ibidem, Rep. Fourth Dist., 1843, p. 77, fig. 5; p. 104, fig. 2.—Billings, Canadian Nat. Geol., I, 1856, p. 59, pl. 1, fig. 5.—Roemer, Sil. Fauna west. Tennessee, 1860, p. 65, pl. 5, fig. 2.

Strophomena undulatus Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 139, fig. 3.

Strophomena undulata Hall, Ibidem, Rep. Fourth Dist., 1843, p. 175, fig. 3.—Yandell and Shumard, Cont. Geol. Kentucky, 1847, p. 11.

Productus? sulcatus Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 39, pl. 13, fig. 7.

Productus sulcifer de Verneuil, Ibidem, 1843, p. 39.

Leptæna tenuistriata Hall, Pal. New York, I, 1847, p. 108, pl. 31A, fig. 4.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 8, figs. 12–16.

Leptæna depressa Hall, Pal. New York, II, 1852, p. 62, pl. 21, fig. 8; p. 257, pl. 53, fig. 6.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 823, fig. 630.

Strophomena rugosa Hall, Pal. New York, III, 1859, p. 195, pl. 19, fig. 1.

Strophomena rhomboidalis Billings, Canadian Jour., VI, 1861, p. 336, figs. 111, 112;—Geol. Canada, 1863, p. 311, fig. 314; p. 367, fig. 373;—Proc. Portland Soc. Nat. Hist., 1863, p. 107, pl. 3, fig. 1.—Hall, Pal. New York, IV, 1867, p. 76, pl. 12, figs. 16–18; p. 414, pl. 15, figs. 15, 16.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 426, pl. 10, fig. 7.—Meek, Pal. Ohio, I, 1873, p. 75, pl. 5, fig. 6.—Billings, Pal. Foss., II, 1874, p. 27.—White, Wheeler's Expl. Survey west 100th Merid., IV, 1875, p. 85, pl. 5, fig. 5 —Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 253, pl. 4, fig. 4.—Hall, Twenty-eighth Rep. New York State Mus. Nat. Hist., 1879, p. 151, pl. 22, figs. 4–10.—Miller, Jour. Cincinnati Soc. Nat. Hist., IV, 1881, p. 1.—Hall, Eleventh Rep. State Geol. Indiana, 1882, p. 288, pl. 22, figs. 4–10;—Second Ann. Rep. New York State Geol., 1883, pl. 38, figs. 17–31.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 118.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 18, pl. 2, figs. 1–13.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 150, pl. 18, figs. 1–3.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 298.—Beecher, American Jour. Sci., 3d ser., XLI, 1891, p. 357, pl. 17, figs. 18–21.—Herrick, Geol. Ohio, VII, 1895, pl. 20, fig. 6.

Strophomena analoga Davidson, Quart. Jour. Geol. Soc. London, XIX, 1863, p. 173, pl. 9, fig. 18.—Dawson, Acadian Geol., 3d ed., 1878, p. 295, fig. 95.

Leptæna quadrilatera Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 65.

Strophomena gibbosa James, Cincinnati Quart. Jour. Sci., I, 1874, p. 333.

Strophomena tenuistriata Miller, Ibidem, II, 1875, p. 55.—Hall, Second Ann. Rep. New York State Geol., 1883, pl. 38, figs. 12–16.

Leptæna rhomboidalis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 279, pl. 8, figs. 17–31; pl. 15A, figs. 40–42; pl. 20, figs. 21–24.—Foerste, Geol. Ohio, VII, 1895, p. 566.

Leptæna (Strophomena) rhomboidalis, Beecher, American Jour. Sci., 3d ser., XLIV, 1892, p. 150, pl. 1, figs. 7–9.

Plectambonites rhomboidalis Keyes, Geol. Survey Missouri, V, 1895, p. 70, fig. 6.

Loc. Generally distributed in the above-given formations throughout America and Europe.

Digitized by Google

Leptæna rhomboidalis ventricosa Hall. Oriskany (Dev.).

Strophomena depressa var. ventricosa Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 55.

Strophomena rugosa var. ventricosa Hall, Pal. New York, III, 1859, p. 417, pl. 94, figs. 2, 3.

Leptæna rhomboidalis var. ventricosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15A, fig. 43.

Loc. Albany and Schoharie counties, New York; Cumberland, Maryland; Cayuga, Ontario.

Leptæna rugosa=L. rhomboidalis.

Leptæna saxea Sardeson=Plectambonites sericeus.

Leptæna sericea Sowerby=Plectambonites sericeus.

Leptæna sordida Billings=Leptella sordida.

Leptæna(?) stelzneri Kayser. Ordovician.

Leptæna stelzneri Kayser, Palæontographica, Suppl., III, 1876, p. 21, pl. 3, fig. 21.

Loc. Guaco, Argentine Republic.

Obs. Since this species has a high ventral area and a perforated deltidium it is probably a Clitambonites.

Leptæna striata Hall=Strophonella striata.

Leptæna subplana Hall=Orthothetes subplanus.

Leptæna subquadrata Hall=Christiania subquadrata.

Leptæna subtenta Hall=Strophomena trentonensis or S. rugosa subtenta.

Leptæna sulcata de Verneuil=Strophomena sulcata.

Leptæna tenuilineata Hall=Rafinesquina tenuilineata.

Leptæna tenuistriata Hall=L. rhomboidalis.

Leptæna transversalis=Plectambonites transversalis.

Leptæna transversalis var. alabamaensis Foerste = Plectambonites transversalis alabamaensis.

Leptæna trilobata Owen=Strophomena trilobata.

Leptæna unicostata Meek and Worthen. Lorraine (Ord.).

Leptæna (n. sp.?) Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 2B, fig. 3. [See specimen in U. S. Nat. Mus., Cat. Invert. Foss., 17908.]

Strophomena unicostata Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 335, pl. 4, fig. 11.—Whitfield, Geol. Wisconsin, IV, 1882, p. 262, pl. 12, fig. 14.

Rafinesquina unicostata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15A, fig. 39; pl. 20, fig. 25.

Leptæna unicostata Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 411, pl. 32, figs. 6–9.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 174.

Loc. Savanna and Wilmington, Illinois; Delafield and Iron Ridge, Wisconsin; Spring Valley and Granger, Minnesota; Lattners, Iowa; Rapids of the Nelson River, Lake Winnipeg, Manitoba.

Leptæna variolata d'Orbigny=Chonetes variolatus.

Leptæna vicina Castelnau=Chonetes vicinus.

LEPTÆNISCA Beecher. Genotype Leptæna concava Hall.

Leptænisca Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 239, pl. 9, figs. 1–5.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 300;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 291.

Digitized by Google

Leptænisca adnascens Hall and Clarke. Lower Helderberg (Dev.).

Leptænisca adnascens Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 301, 352, pl. 15A, figs. 22, 23.

Loc. Near Clarksville, New York.

Leptænisca concava Hall. Lower Helderberg (Dev.).

Leptæna concava Hall, Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 47;—Pal. New York, III, 1859, p. 197, pl. 18, fig. 2.

Leptæna? (subgenus?) concava Hall, Second Ann. Rep. New York State Geol., 1883, pl. 46, figs. 30, 31.

Leptænisca concava Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 238, pl. 9, figs. 1–5.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 300, pl. 15, figs. 30, 31; pl. 15A, figs. 19–21.

Loc. Albany County, New York; Decatur County, Tennessee.

Leptænisca tangens Hall and Clarke. Lower Helderberg (Dev.).

Leptænisca tangens Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 301, 352, pl. 15A, figs. 24–30.

Loc. Near Clarksville, New York.

LEPTELLA Hall and Clarke. Genotype Leptæna sordida Billings.

Leptella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 293;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 277.

Leptella decipiens (Billings). Calciferous (Ord.).

Leptæna decipiens Billings, Pal. Fossils, I, 1862, p. 74, fig. 67; p. 219;—Geol. Canada, 1863, p. 231, fig. 243.

Leptella decipiens Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 294.

Loc. Point Levis, Canada; Portland Creek, Newfoundland.

Leptella sordida (Billings). Calciferous (Ord.).

Leptæna sordida Billings, Pal. Fossils, I, 1862, p. 73, fig. 66;—Geol. Canada, 1863, p. 231, fig. 242.

Leptella sordida Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 293, pl. 15A, figs. 12–16.

Loc. Point Levis, Canada.

LEPTOBOLUS Hall. Genotype L. lepis Hall.

Leptobolus Hall, Description n. sp. Foss. from Hudson River Group, 1871, p. 3;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 226.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 73, 165;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 241.

Leptobolus grandis Matthew. Lowest Ordovician.

Leptobolus grandis Matthew, Trans. Royal Soc. Canada, X, 1874, p. 91, pl. 16, fig. 7.

Loc. Hardingville, New Brunswick.

Leptobolus insignis Hall. Utica (Ord.).

Leptobolus insignis Hall, Descrip. n. sp. Foss. from Hudson River Group, 1871, p. 3, pl. 3, fig. 17;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 227, pl. 7, fig. 17.—Nicholson, Pal. Province Ontario, 1875, p. 85.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 74, pl. 3, figs. 1–6.

Loc. Middleville, Utica, etc., New York; Ottawa, Canada; Cincinnati, Ohio.

Leptobolus lepis Hall. Utica (Ord.).

Leptobolus lepis Hall, Description n. sp. Foss. from Hudson River Group, 1871, p. 3, pl. 3, figs. 19, 20;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 226, pl. 7, figs. 19, 20.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 69, pl. 1, figs. 10, 11.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 11.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 74, pl. 3, figs. 8–10.

Loc. Cincinnati, Ohio.

Digitized by Google

Leptobolus occidentalis Hall. Maquoketa (Ord.).

Leptobolus occidentalis Hall, Description n. sp. Foss. from Hudson River Group, 1871, p. 3, pl. 3, fig. 18;—Twenty-fourth Rep. New York State Cab. Nat. Hist., 1872, p. 227, pl. 7, fig. 18.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 3, fig. 7.

Loc. Hawleys Mills, Iowa; Platteville, Wisconsin; Ottawa, Canada (Ami).

Leptocœlia Hall = Anoplotheca.

Leptocœlia propria Hall = Anoplotheca flabellites.

Leptocœlia disparilis Hall = Atrypina disparilis.

Leptocœlia imbricata Hall = Atrypina imbricata.

LEPTOSTROPHIA Hall and Clarke.

Genotype Stropheodonta magnifica Hall.

Leptostrophia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 288;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 281.

Obs. This is a subdivision of Stropheodonta. The following species have been referred to it: S. magnifica, S. perplana, S. textilis, S. beckei, S. magniventra, S. junia, S. irene, S. blainvillei, and S. tullia.

LINDSTRŒMELLA Hall and Clarke. Genotype L. aspidium H. and C.

Lindstrœmella Hall and Clarke, Extract Pal. New York, VIII, 1890, p. 134;—Pal. New York, VIII, Pt. I, 1892, p. 134;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 257.

Lindstrœmella aspidium Hall and Clarke. Hamilton (Dev.).

Lindstrœmella aspidium Hall and Clarke, Extract Pal. New York, VIII, 1890, p. 134, pl. 4E, figs. 25–28;—Pal. New York, VIII, Pt. I, 1892, pp. 134, 178, pl. 4E, figs. 25–28.

Loc. Leonardsville, Hamilton, Darien, etc., New York.

LINGULA Bruguière. Genotype Lingula anatina Lamarck.

Lingula Bruguière, Encyclopédie Méthodique, I, 1792, pl. 250.—Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 172, 1864, p. 68.—Hall, Pal. New York, IV, 1867, p. 5.—Dall, American Jour. Conch., VI, 1870, pp. 153, 154.—Meek, Hayden's U. S. Geol. Survey Terr., IX, 1876, p. 7.—Dall, Bull. U. S. Nat. Museum, 8, 1877, p. 43.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 2, 161.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 338.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 226.

Lingula acuminata Hall = Lingulepis acuminata.

Lingula acutangula Roemer = Lingulepis acutangulus.

Lingula acutirostris Hall. Clinton (Sil.).

Lingula acutirostra Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 77, fig. 9 on p. 76;—Pal. New York, II, 1852, p. 56, pl. 20, fig. 5.

Loc. Wolcott, New York.

Obs. Based upon a single specimen now lost.

Lingula æqualis Hall. Trenton (Ord.).

Lingula æqualis Hall, Pal. New York, I, 1847, p. 95, pl. 30, fig. 3.—Walcott, Proc. U. S. Nat. Mus., XI, 1888, p. 480, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 9, fig. 4.

Loc. Middleville, Trenton Falls, and Rome, New York.

Lingula alba-pinensis Walcott. Upper Devonian.

Lingula albapinensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 108, pl. 2, fig. 1.

Loc. White Pine district, Nevada.

Digitized by Google

Lingula alveata Hall=Dignomia alveata.

Lingula ampla Owen=Lingulella ampla.

Lingula antiqua Emmons=Lingulepis acuminata.

Lingula antiqua Hall, 1851, 1862, Hayden, 1863 (non Hall, 1847)=Lingulepis pinniformis.

Lingula antiquata Emmons=Lingulepis acuminata.

Lingula artemis Billings. Gaspé No. 5 (L. Dev.).

Lingula artemis Billings, Pal. Fossils, II, 1874, p. 14, fig. 4.

Loc. Gaspé, Cape Bon Ami.

Lingula atra Herrick. Waverly (L. Carb.).

Lingula atra Herrick, Bull. Denison Univ., IV, 1888, pp. 13, 16, pl. 10, fig. 30;—Geol. Ohio, VII, 1895, pl. 22, figs. 5, 6.

Loc. Cuyahoga River, Ohio.

Lingula attenuata Hall=Glossina trentonensis.

Lingula aurora Hall=Lingulella aurora.

Lingula aurora var. Hall=Lingulella stoneana.

Lingula belli Billings. Chazy (Ord.).

Lingula belli Billings, Canadian Nat. Geol., IV, 1859, p. 431, figs. 7, 8;—Geol. Canada, 1863, p. 124, fig. 47.

Loc. Island of Montreal, Allumette Island, Canada.

Lingula beltrami Winchell and Schuchert. Lorraine (Ord.).

Lingula beltrami Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 351, figs. 25a, 25b.

Loc. Spring Valley, Minnesota.

Lingula bicarinata Ringueberg. Niagara (Sil.).

Lingula bicarinata Ringueberg, Proc. Acad. Nat. Sci. Philadelphia, 1884, p. 149, pl. 3, fig. 8.—Miller, N. American Geol. Pal., 1889, p. 349.

Loc. Lockport, New York.

Lingula billingsana Whitcaves=Lingulella billingsana.

Lingula bisulcata Ulrich. Utica (Ord.).

Lingula bisulcata Ulrich, American Geologist, III, 1889, p. 380, fig. 2, on p. 378.

Loc. Ludlow, Kentucky.

Lingula brevirostris Meek and Hayden. Jurassic.

Lingula brevirostris Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1858, p. 50;—Ibidem, 1860, p. 419;—Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 172, 1865, p. 69, pl. 3, fig. 3.—Whitfield, Powell's Geol. Geogr. Survey Rocky Mt. Region, 1880, p. 346, pl. 3, figs. 4, 5.

Loc. Black Hills, Dakota.

Lingula briseis Billings. Trenton (Ord.).

Lingula briseis Billings, Pal. Fossils, I, 1862, p. 48, fig. 52;—Geol. Canada, 1863, p. 161, fig. 136.

Loc. Bayonne River, Canada.

Lingula (??) calumet N. H. Winchell. ?Cambrian.

Lingula calumet N. H. Winchell, Thirteenth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1885, p. 65.—Miller, N. American Geol. Pal., 1889, p. 349.

Loc. Pipestone, Minnesota.

Obs. It is not certain that these specimens are organic.

Digitized by Google

Lingula(?) canadaensis Billings. Trenton and Lorraine (Ord.).

Lingula canadensis Billings, Pal. Fossils, I, 1862, p. 114, fig. 95;—Geol. Canada, 1863, p. 210, fig. 209.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 27.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 352, fig. 26.

Loc. Anticosti; in the Galena at Mantorville and Hader, Minnesota.

Lingula carbonaria Shumard. Upper Carboniferous.

Lingula carbonaria Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 215.

Loc. Clarke County, Missouri.

Lingula centrilineata Hall. Lower Helderberg (Dev.).

Lingula centrilineata Hall, Pal. New York, III, 1859, p. 155, pl. 9, figs. 1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 15.

Loc. Albany County, New York.

Lingula ceryx Hall. Schoharie (Dev.).

Lingula ceryx Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 19;—Pal. New York, IV, 1867, p. 5, pl. 2, fig. 1.

Loc. Clarkesville, New York.

Lingula cincinnatiensis Hall and Whitfield. Lorraine (Ord.).

Lingulella (Dignomia) cincinnatiensis Hall and Whitfield, Pal. Ohio, II, 1875, p. 67, pl. 1, figs. 2, 3.

Lingulella cincinnatiensis Miller, American Pal. Foss., 1877, p. 115.

Loc. Cincinnati, Ohio.

Lingula clathrata Winchell and Schuchert. Trenton (Ord.).

Lingula clathrata Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 345, pl. 29, fig. 42.

Loc. St. Paul, Minnesota.

Lingula clintoni Vanuxem. Clinton (Sil.).

Lingula oblonga Conrad (non Eichwald), Third Ann. Rep. Geol. Survey New York, 1839, p. 65.—Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 77, fig. 4;—Pal. New York, II, 1852, p. 54, pl. 20, fig. 1.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 823, fig. 629.

Lingula clintoni Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 79, fig. 4.

Lingula suboblonga d'Orbigny, Prodrome Pal. Stratig., 1850, p. 34.

Loc. Cayuga County, New York; Pennsylvania; Hamilton, Ontario; Arisaig, Nova Scotia (Honeyman and Ami).

Lingula cobourgensis Billings. Trenton (Ord.).

Lingula cobourgensis Billings, Pal. Fossils, I, 1862, p. 50, fig. 54;—Geol. Canada, 1863, p. 161, fig. 132.

Lingula cobourgensis? Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 346, pl. 29, fig. 12.

Loc. Cobourg and Colingwood, Canada; ?Minneapolis, Minnesota; in the Utica at Ottawa, Canada (Ami).

Lingula coheni A. Ulrich. Middle Devonian.

Lingula coheni A. Ulrich, N. Yahrb. f. Mineral., Beilageband, VIII, 1892, p. 82, pl. 5, fig. 11.

Loc. Near Pulquina, Bolivia.

Lingula complanata Williams. Hamilton-Ithaca (Dev.).

Lingula nuda Hall, Pal. New York, IV, 1867, pl. 2, fig. 4 (not figs. 5, 6).

Lingula complanata Williams, Proc. American Ass. Adv. Sci., XXX, 1882, p. 188;—Bull. U. S. Geol. Survey, 3, 1884, pp. 14, 15, 20, 22.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 1, fig. 17.

Loc. Ithaca and Canandaigua Lake, New York.

Digitized by Google

Lingula compta Hall and Clarke. Hamilton (Dev.).

Lingula compta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 171, pl. 1, fig. 16.

Loc. Canandaigua Lake, New York.

Lingula concentrica Vanuxem=Schizobolus concentricus.

Lingula concentrica Conrad. ? Corniferous (Dev.).

Lingula concentrica Conrad, Third Ann. Rep. Geol. Survey New York, 1839, p 64.

Loc. "Helderberg Mountains," New York.

Obs. Insufficiently defined to be recognized.

Lingula covingtonensis Hall and Whitfield. Utica (Ord.).

Lingula covingtonensis Hall and Whitfield, Pal. Ohio, II, 1875, p. 67, pl. 1, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 8.

Loc. Covington, Kentucky.

Lingula crassa Hall=Glossina crassa.

Lingula crawfordsvillensis Gurley. Keokuk (L. Carb.).

Lingula crawfordsvillensis Gurley, New Carboniferous Foss., 1, 1883, p. 2.—Miller, N. American Geol. Pal., 1889, p. 350.

Loc. Crawfordsville, Indiana.

Obs. Should be compared with L. varsaviensis.

Lingula cuneata Conrad. Medina (Sil.).

Lingula cuneata Conrad, Third Ann. Rep. Geol. Survey New York, 1839, pp. 63, 64.—Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 48, fig. 5;—Pal. New York, II, 1852, p. 8, pl. 4, fig. 2.—Hall and Clarke, Pal. New York, VIII Pt. I, 1892, p. 12, pl. 1, figs. 11, 12; pl. 4K, fig. 9.

Lingulella cuneata Miller, N. American Geol. Pal., 1889, p. 352.

Loc. Medina and Lockport, New York.

Lingula curta Conrad. Trenton-Utica (Ord.).

Lingula curta Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 266, pl. 15, fig. 12.—Hall, Pal. New York, I, 1847, p. 97, pl. 30, fig. 6.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 818, fig. 604.—Billings, Geol. Canada, 1863, p. 161, fig. 138; p. 201, fig. 197.—Emerson, Geol. Frobischer Bay; Nourse's Narr. Hall's Arctic Exped., App., III, 1879, p. 578.

Loc. East Canada Creek and Middleville, New York; Carlisle, etc., Pennsylvania; Montmorency Falls, Canada; Frobischer Bay.

Lingula cuyahoga Hall. Chemung-Waverly (Dev.-L. Carb.).

Lingula cuyahoga Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 24;—Pal. New York, IV, 1867, p. 15, pl. 1, fig. 5.—Herrick, Bull. Denison Univ., IV, 1888, p. 13;—Geol. Ohio, VII, 1895, pl. 22, fig. 9.

Lingula cuyahoga? Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 1, fig. 18.

Loc. Akron and Cuyahoga Falls, Ohio; Chemung group, Panama, New York.

Lingula cyane Billings=Glossina cyane.

Lingula daphne Billings=Glossina trentonensis.

Lingula dawsoni Matthew=Lingulella dawsoni.

Lingula delia Hall. Hamilton (Dev.).

Lingula delia Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 22;—Pal. New York, IV, 1867, p. 12, pl. 2, fig. 9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 15, pl. 1, fig. 29.

Loc. Canandaigua Lake, New York.

Lingula densa Hall. Hamilton (Dev.).

Lingula densa Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 22;—Pal. New York, IV, 1867, p. 11, pl. 2, figs. 10, 11.

Digitized by Google

Lingula densa Hall—Continued.

Lingula densa? Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 15, pl. 1, fig. 23.

Loc. Summit and Centerfield, New York.

Lingula desiderata Hall. Corniferous (Dev.).

Lingula desiderata Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 19;—Pal. New York, IV, 1867, p. 6, pl. 2, fig. 2.

Loc. Ontario County, New York.

Lingula(?) dolata Sardeson. Calciferous (Ord.).

Lingula dolata Sardeson, Bull. Minnesota Acad. Nat. Sci., IV, 1896, pl. 6, fig. 12.

Loc. Stillwater, Minnesota.

Lingula dubia d'Orbigny=Glossina dubia.

Lingula elderi Whitfield. Trenton and Lorraine (Ord.).

Lingula elderi Whitfield, American Jour. Sci., 3d ser., XIX, June, 1880, p. 472, figs. 1, 2;—Geol. Wisconsin, IV, 1882, p. 345, pl. 27, figs. 1–5.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 11, pl. 1, figs. 21, 22.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 339, pl. 29, figs. 1–4.

Lingula minnesotensis N. H. Winchell, Eighth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, July, 1880, p. 61.

Loc. Rochester, Minneapolis, etc., Minnesota; Beloit, Wisconsin; Cincinnati, Ohio.

Lingula elegantula Shaler=L. rectilateralis.

Lingula elliptica Hall (non Phillips)=L. subelliptica.

Lingula(?) elliptica Emmons. Cambrian.

Lingula elliptica Emmons (non Phillips, 1836), American Geology, Pt. II, 1855, p. 112.

Loc. Augusta County, Virginia.

Obs. This species belongs to another genus. The specific name will therefore not conflict with that of Phillips.

Lingula elongata Hall. Trenton (Ord.).

Lingula elongata Hall, Pal. New York, I, 1847, p. 97, pl. 30, fig. 5.—Billings, Geol. Canada, 1863, p. 161, fig. 135.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 165.

Loc. Lewis County, New York; Lake Winnipeg, Manitoba; Ottawa, Canada, in the Utica terrane (Ami).

Lingula ererensis Rathbun. Middle Devonian.

Lingula ererensis Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 16.

Loc. Erere, Province of Para, Brazil.

Lingula exilis Hall=Lingulodiscina exilis.

Lingula eva Billings. Black River (Ord.).

Lingula eva Billings, Canadian Nat. Geol., VI, 1861, p. 150;—Geol. Canada, 1863, p. 141, fig. 73.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 341, pl. 29, figs. 5, 6.

Loc. Murray Bay, Canada; Fremont, Winona County, Minnesota.

Lingula forbesi Billings. Lorraine (Ord.).

Lingula forbesi Billings, Pal. Fossils, I, 1862, p. 115, fig. 96.

Loc. Anticosti.

Lingula gannensis Herrick. Waverly (L. Carb.).

Lingula gannensis Herrick, Bull. Denison Univ., IV, 1888, pp. 12, 17, pl. 3, figs. 2, 3;—Geol. Ohio, VII, 1895, pl. 22, figs. 2, 3.

Loc. Gann, Knox County, Ohio.

Digitized by Google

Lingula gibbosa Hall. Niagara (Sil.).

Lingula gibbosa Hall, Description n. sp. Foss. Waldron, Indiana, 1879, p. 13;—Eleventh Rep. State Geol. Indiana, 1882, p. 284, pl. 27, fig. 2;—Trans. Albany Institute, X, 1883, p. 69.

Loc. Waldron, Indiana.

Lingula gorbyi Miller. Chouteau (L. Carb.).

Lingula gorbyi Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 309, pl. 9, figs. 3, 4.

Loc. Sedalia, Missouri.

Lingula gracana Rathbun. Middle Devonian.

Lingula gracana Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 259, fig. 2.

Loc. Erere, Province of Para, Brazil.

Lingula halli White. Burlington (L. Carb.).

Lingula halli White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 30.

Loc. Burlington, Iowa.

Lingula howleyi Matthew. Lower Ordovician.

Lingula howleyi Matthew, Trans. Royal Soc. Canada, 2d ser., I, 1896, p. 259, pl. 1, fig. 3.

Loc. Kelleys Island, Conception Bay, Newfoundland.

Obs. Appears to be a synonym for L. murrayi Billings.

Lingula hurlbuti N. H. Winchell = Glossina hurlbuti.

Lingula huronensis Billings. Chazy (Ord.).

Lingula huronensis Billings, Canadian Nat. Geol., IV, 1859, p. 433, fig. 9;—Geol. Canada, 1863, p. 124, fig. 48.

Loc. St. Joseph Island, Lake Huron.

Lingula indianaensis Miller and Gurley. Keokuk (L. Carb.).

Lingula indianensis Miller and Gurley, Bull. Illinois State Mus. Nat. Hist., 3, 1893, p. 69, pl. 7, fig. 1.

Loc. Crawfordsville, Indiana.

Lingula ingens Spencer. Niagara (Sil.).

Lingula ingens Spencer, Bull. Univ. State Missouri, 1884, p. 56;—Trans. St. Louis Acad. Sci., IV, 1886, p. 606, pl. 8, fig. 6.

Loc. Hamilton, Ontario.

Lingula insularis Billings. Anticosti (Sil.).

Lingula insularis Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 40.

Loc. Anticosti.

Lingula iole Billings. Calciferous (Ord.).

Lingula iole Billings, Pal. Fossils, I, 1865, p. 215, fig. 199.

Loc. Near Portland Creek, Newfoundland.

Lingula iowaensis Owen. Galena (Ord.).

Lingula iowensis Owen, Geol. Rep. Iowa, Wisconsin, and Illinois, 1844, p. 70, pl. 15, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 8, pl. 1, fig. 14.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 349, pl. 29, figs. 19–22.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 164.

Lingula quadrata? Owen (not Eich.), Geol. Rep. Wisconsin, Iowa, and Minnesota, 1851, pl. 2B, fig. 8. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17873.]

Lingula quadrata Hall, Geol. Wisconsin, I, 1862, p. 46, fig. 1, and p. 435.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 305, pl. 2, fig. 4.

Lingulella iowensis Whitfield, Geol. Wisconsin, IV, 1882, p. 242, pl. 9, fig. 1.

Loc. Wisconsin; Iowa; Minnesota; Illinois; Lake Winnipeg, Manitoba.

Digitized by Google

Lingula irene Billings=Lingulella irene.

Lingula iris Billings. Calciferous (Ord.).

Lingula iris Billings, Pal. Fossils, I, 1865, p. 301, fig. 290.

Loc. Point Levis, Canada.

Lingula kingstonensis Billings. Black River (Ord.).

Lingula kingstonensis Billings, Pal. Fossils, I, 1862, p. 48, fig. 51;—Geol. Canada, 1863, p. 141, fig. 74.

Loc. Long Island, near Kingston, Canada.

Lingula lamellata Hall, 1852 (partim, non Hall, 1843)=L. tæniola.

Lingula lamellata Hall. Niagara (Sil.).

Lingula lamellata Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 108, fig. 2;—Pal. New York, II, 1852, p. 249, pl. 53, figs. 1, 2 (non p. 55, pl. 20, fig. 4=L. tæniola).—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 16, pl. 1, figs. 9, 10; pl. 4K, figs. 10–13.

Loc. Lockport and Rochester, New York; Hamilton, Ontario.

Lingula leana Hall=Glossina leana.

Lingula ligea Hall. Hamilton–Portage (Dev.).

Lingula ligea Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 76;—Pal. New York, IV, 1867, p. 7, pl. 1, fig. 2.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 107, pl. 2, fig. 2.—Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 62.

Lingula ligea var. Hall, Pal. New York, IV, 1867, p. 8, pl. 2, fig. 8.

Lingula ligea? Whitfield, Annals New York Acad. Sci., V, 1891, pp. 547, 573, pl. 11, figs. 3, 4;—Geol. Ohio, VII, 1895, p. 441, pl. 7, figs. 3, 4; p. 462.

Loc. Seneca Lake, Ithaca, etc., New York; Thedford, Ontario (Whiteaves); Delaware County, Ohio (Whitfield); Eureka district, Nevada.

Lingula ligea nevadaensis Walcott. Lower Devonian.

Lingula ligea var. nevadensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 107, pl. 2, fig. 3.

Loc. Eureka district, Nevada.

Lingula lingulata Hall and Clarke. Clinton (Sil.).

Lingula lingulata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 173, pl. 4K, fig. 5.

Loc. Hamilton, Ontario.

Lingula lonensis Walcott. Lower Devonian.

Lingula lonensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 108, pl. 13, fig. 1.

Loc. Lone Mountain, Nevada.

Lingula lucretia Billings. Gaspé No. 5 (Dev.).

Lingula lucretia Billings, Pal. Fossils, II, 1874, p. 14, fig. 3.

Loc. Cape Bon Ami, Gaspé.

Lingula lyelli Billings. Chazy (Ord.).

Lingula lyelli Billings, Canadian Nat. Geol., IV, 1859, p. 348, fig. 1; p. 431;—Geol. Canada, 1863, p. 124, fig. 49.

Loc. Alumette Island.

Lingula maida Hall. Hamilton (Dev.).

Lingula maida Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 20;—Pal. New York, IV, 1867, p. 9, pl. 2, fig. 13.

Loc. Moscow, New York.

Digitized by Google

Lingula manni Hall. Corniferous (Dev.).

Lingula manni Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 20;—Pal. New York, IV, 1867, p. 6, pl. 2, fig. 3.—Whitfield, Annals New York Acad. Sci., V, 1891, p. 546, pl. 11, figs. 1, 2;—Geol. Ohio, VII, 1895, p. 441, pl. 7, figs. 1, 2.

Loc. Delaware County, Ohio.

Lingula mantelli Billings. Calciferous (Ord.).

Lingula mantelli Billings, Canadian Nat. Geol., IV, 1859, p. 349, figs. 1e–1f;—Geol. Canada, 1863, p. 113, fig. 20.

Loc. St. Eustache, Canada.

Lingula (?) manticula White. Upper Cambrian.

Lingula? manticula White, Wheeler's Expl. Survey west 100 Merid., Prel. Rep., 1874, p. 9;—Ibidem, Final Rep., IV, 1875, p. 52, pl. 3, fig. 2.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 13, pl. 9, fig. 3; pl. 11, fig. 2.

Loc. Schell Creek Range, Nevada.

Lingula marginata d'Orbigny (non Phillips)=L. submarginata.

Lingula matthewi Hartt=Acrothele matthewi.

Lingula meeki Herrick. Waverly (L. Carb.).

Lingula meeki Herrick, Bull. Denison Univ., IV, 1888, pp. 13, 18, pl. 10, fig. 31;—Geol. Ohio, VII, 1895, pl. 22, figs. 7, 8.

Loc. Cuyahoga Valley, Ohio.

Lingula melie Hall. Waverly (L. Carb.).

Lingula melie Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 24;—Pal. New York, IV, 1867, p. 14, pl. 1, figs. 3, 4.—Meek, Pal. Ohio, II, 1875, p. 276, pl. 14, fig. 3.—Herrick, Bull. Denison Univ., IV, 1888, p. 13.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 12, fig. 9; pl. 1, fig. 32.—Herrick, Geol. Ohio, VII, 1895, pl. 20, fig. 1; pl. 22, fig. 10.

Loc. Chagrin Falls and Berea, Ohio.

Lingula membranacea Winchell. Waverly (L. Carb.).

Lingula membranacea A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 3.—Herrick, Bull. Denison Univ., IV, 1888, pp. 12, 17, pl. 3, fig. 4;—Geol. Ohio, VII, 1895, pl. 22, fig. 4.

Lingula (Lingulella?) membranacea Meek, Pal. Ohio, II, 1875, p. 275, pl. 14, fig. 4.

Loc. Burlington, Iowa; Harts Grove and Loudonville, Ohio; Shafers, Pennsylvania.

Lingula metensis Terquem? Lower Lias (Jurassic).

Lingula cf. metensis (Terquem) Möricke, Neues Jahrbuch f. Mineral., Beilageband, IX, 1894, p. 58, pl. 5, fig. 10.

Loc. Sierra de la Ternera; Mine Amolanes, Chile.

Lingula minnesotensis N. H. Winchell=L. elderi.

Lingula minuta Meek. Hamilton (Dev.).

Lingula minuta Meek, Trans. Chicago Acad. Sci., I, 1868, p. 87, pl. 13, fig. 1.

Loc. Near Fort Resolution, Great Slave Lake, British America.

Lingula modesta E. O. Ulrich. Trenton-Lorraine (Ord.).

Lingula modesta Ulrich, American Geologist, III, 1889, p. 382, fig. 4 on p. 378.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 344, pl. 29, fig. 41.

Lingula vanhorni Hall and Clarke (non Miller), Pal. New York, VIII, Pt. I, 1892, pl. 1, fig. 4.

Loc. Covington and Frankfort, Kentucky; Lattners, Iowa; Granger and Wykoff, Minnesota.

Digitized by Google

Lingula morsei (N. H. Winchell). St. Peters (Ord.).

Lingulepis morsensis N. H. Winchell, Fourth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1876, p. 41, fig. 6.

Lingulepis morsii Miller, N. American Geol. Pal., 1889, p. 352.

Lingula morsii Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 62.—Sardeson, Bull. Minnesota Acad. Nat. Sci., IV, 1896, p. 77, pl. 4, figs. 2, 3.

Loc. Near Fountain, Minnesota.

Lingula mosia Hall. Upper Cambrian.

Lingula mosia Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 126, pl. 6, figs. 1-3;—Trans. Albany Institute, V, 1867, p. 102.—Sardeson, Bull. Minnesota Acad. Nat. Sci., IV, 1896, p. 95.

Loc. Lagrange Mountain, Minnesota; Mazomanie, Wisconsin.

Lingula münsteri d'Orbigny. Ordovician.

Lingula münsterii d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 29, pl. 2, fig. 6.

Lingula münsteri A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 7.

Loc. Tacopaya, etc., Bolivia.

Lingula(?) murrayi Billings. Upper Cambrian.

Lingula murrayi Billings, Canadian Nat. Geol., n. ser., VI, 1872, p. 467, fig. 3;—Pal. Fossils, II, 1874, p. 66, fig. 34.

Loc. Bell Island, Conception Bay, Newfoundland.

Obs. See Lingula howleyi.

Lingula mytiloides Sowerby. Upper Carboniferous.

Lingula mytiloides Sowerby, Mineral Conchology, I, 1813, p. 55, tab. 19, figs. 1, 2.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 572, pl. 25, fig. 2.

Loc. Illinois.

Lingula nitida Meek and Hayden. Upper Cretaceous.

Lingula nitida Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 443.—Meek, Rep. U. S. Geol. Survey Terr., IX, 1876, p. 9, pl. 28, fig. 18.—White, Eleventh Rep. U. S. Geol. Survey Terr., 1879, p. 205.—Whiteaves, Cont. Canadian Pal., I, 1885, p. 29.

Loc. Mouth of Big Horn River, Nebraska; Sage Creek, Colorado; Near Irvine Station, Canadian Pacific Railroad, Canada.

Lingula norwoodi James=Lingulops norwoodi.

Lingula nuda Hall (partim)=L. complanata.

Lingula nuda Hall. Hamilton (Dev.).

Lingula nuda Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 22;—Pal. New York, IV, 1867, p. 10, pl. 2, figs. 5, 6 (non fig. 4=L. complanata).

Loc. Canandaigua Lake, New York.

Lingula nympha Billings. Calciferous (Ord.).

Lingula nympha Billings, Pal. Fossils, I, 1865, p. 214, fig. 198.

Loc. Table Head, Newfoundland.

Lingula oblata Hall. Clinton (Sil.).

Lingula oblata Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 77, fig. 8 on p. 76;—Pal. New York, II, 1852, p. 54, pl. 20, fig. 2.

Loc. Sodus and Wolcott, New York.

Lingula oblonga Conrad (non Eichwald)=L. clintoni.

Lingula obtusa Hall. Trenton-Utica (Ord.).

Lingula obtusa Hall, Pal. New York, I, 1847, p. 98, pl. 30, fig. 7.—Billings, Geol. Canada, 1863, p. 161, fig. 137.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 165.

Loc. Middleville, New York; Lake Winnipeg and Ottawa, Canada.

Digitized by Google

Lingula paliformis Hall = Lingulella paliformis.

Lingula papillosa Emmons. Trenton (Ord.).

Lingula papillosa Emmons, American Geology, Pt. II, 1855, p. 202, fig. 64;—Manual Geol., 1860, p. 99, fig. in text.

Loc. Unknown.

Lingula paracletus Hall and Clarke. Waverly (L. Carb.).

Lingula paracletus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 10, 12, fig. 8; p. 172.

Loc. Chardon, Ohio.

Lingula parrishi Miller. Upper Carboniferous.

Lingula parrishi Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 307, pl. 8, fig. 2; pl. 9, fig. 1.

Loc. Kansas City, Missouri.

Lingula perlata Hall. Lower Helderberg (Dev.).

Lingula perlata Hall, Pal. New York, III, 1859, p. 156, pl. 9, figs. 3–5.

Loc. Albany and Schoharie counties, New York.

Lingula perovata Hall = Glossina perovata.

Lingula perplexa Hall = L. subelliptica.

Lingula perryi Billings. ? Chazy (Ord.).

Lingula perryi Billings, Pal. Fossils, I, 1861, p. 20, fig. 23;—Geol. Vermont, II, 1861, p. 957, fig. 363;—Geol. Canada, 1863, p. 274, fig. 278.

Loc. Highgate Spring, Vermont.

Lingula philomela Billings. Trenton and Lorraine (Ord.).

Lingula philomela Billings, Pal. Fossils, I, 1862, p. 49, fig. 53;—Geol. Canada, 1863, p. 161, fig. 133.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 1, fig. 8.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 342, pl. 29, figs. 7, 8.

Loc. Montmorency Falls, Ottawa, etc., Canada; Florenceville, Iowa.

Lingula plagemanni Möricke. Jurassic.

Lingula plagemanni Möricke, Neues Jahrbuch f. Mineral., Beilageband, IX, 1894, p. 59, pl. 5, fig. 9.

Loc. Canales and Caracoles, Bolivia.

Lingula pinnaformis Hall = Lingulepis pinniformis.

Lingula polita Hall = Obolella polita.

Lingula prima Hall = Lingulepis prima.

Lingula procteri Ulrich = L. vanhorni.

Lingula progne Billings. Trenton-Utica (Ord.).

Lingula progne Billings, Pal. Fossils, I, 1862, p. 47, fig. 50;—Geol. Canada, 1863, p. 161, fig. 134; p. 201, fig. 196.

Loc. Montreal, Collingwood, Ottawa, etc., Canada.

Lingula punctata Hall. Hamilton and Ithaca (Dev.).

Lingula punctata Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 21;—Pal. New York, IV, 1867, p. 10, pl. 1, fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 11, 17, pl. 1, figs. 26–28.

Loc. Canandaigua Lake and Summit, New York; Portage group at Ithaca (Williams).

Lingula quadrata, American authors = L. rectilateralis and L. iowaensis.

Digitized by Google

Lingula quebecensis Billings. Upper Cambrian and Calciferous.

Lingula quebecensis Billings, Pal. Fossils, I, 1862, p. 72, fig. 65; pp. 72, 216;—Geol. Canada, 1863, p. 230, fig. 241.

Loc. Point Levis, Sillery, etc., Canada; Cow Head, Newfoundland.

Lingula rectilatera Hall. Lower Helderberg (Dev.).

Lingula rectilatera Hall, Pal. New York, III, 1859, p. 156, pl. 9, figs 6–8.

Loc. Albany and Schoharie counties, New York; Arisaig, Nova Scotia (Ami).

Lingula rectilateralis Emmons. Trenton-Lorraine (Ord.).

Lingula rectilateralis Emmons, Geol. New York; Rep. Second Dist., 1842, p. 399, fig. 6.

Lingula quadrata Hall (non Eichwald), Pal. New York, I, 1847, p. 96, pl. 30, fig. 4; p. 285, pl. 79, fig. 1.—Billings, Canadian Nat. Geol., I, 1856, p. 319, fig. 8.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 820, fig. 615.—Billings, Geol. Canada, 1863, p. 161, fig. 131;—Catalogue Sil. Foss. Anticosti, 1866, p. 10.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 1, fig. 13.

Lingula elegantula Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 61.

?Lingula quadrata Miller, Cincinnati Quart. Jour Sci., II, 1875, p. 9.

Loc. Rodman, Lorraine, Middleville, Trenton Falls, etc., New York; Ottawa etc., Canada; Anticosti.

Obs. This species is more closely related to L. iowaensis than to L. quadrata Eichwald.

Lingula riciniformis Hall. Trenton (Ord.).

Lingula riciniformis Hall, Pal. New York, I, 1847, p. 95, pl. 30, fig. 2.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 343, fig. 24; pl. 29, fig 9.

Lingula (Glossina) riciniformis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 1, fig. 3.

Loc. Middleville, New York; Charlesbourg, Canada; St. Paul, Minnesota.

Lingula riciniformis galenaensis Winchell and Schuchert. Trenton (Ord.).

Lingula riciniformis var. galenensis Winchell and Schuchert, American Geol., IX, 1892, p. 284;—Minnesota Geol. Survey, III, 1893, p. 344, pl. 29, figs. 10, 11.

Loc. Near Kenyon and Fountain, Minnesota; Neenah and Oshkosh, Wisconsin.

Lingula rodriguezii Rathbun. Middle Devonian.

Lingula rodriguezii Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 260.

Loc. Erere, Province of Para, Brazil.

Lingula scotica Meek (non Davidson)=Glossina waverlyensis.

Lingula scotica var. nebraskensis Meek=Glossina nebraskensis.

Lingula scutella Hall and Clarke. Chemung (Dev.).

Lingula scutella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 171, pl. 1, fig. 30.

Loc. Alleghany County, New York.

Lingula shumardi Cragin. Lower Cretaceous.

Lingula shumardi Cragin, Geol. Survey Texas; Fourth Ann. Rep., 1893, p. 166.

Loc. Bonham-Sherman road, Fannin County, Texas.

Lingula spathata Hall. Lower Helderberg (Dev.).

Lingula spathata Hall, Pal. New York, III, 1859, p. 157, pl. 9, figs. 7, 9, 11.

Loc. Albany and Schoharie counties, New York; Arisaig, Nova Scotia (Ami).

Lingula spatiosa Hall=Glossina spatiosa.

Lingula spatulata Vanuxem. Genesee and Portage (Dev.).

Lingula spatulata Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 168, fig. 3.—Hall, Ibidem, Rep. Fourth Dist., 1843, p. 223, fig. 3;—Pal. New York, IV, 1867, p. 13, pl. 1, fig. 1.—Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 25.—

Digitized by Google

Lingula spatulata Vanuxem—Continued.

Tschernyschew, Mémoires du Comité Géologique de St. Pétersbourg, 1887, p. 116, pl. 14, fig. 29.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 1, fig. 15.

Lingula spatulata? Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 258, fig. 1;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 16.

Loc. Lodi, Seneca Lake, etc., New York; Portage group at Ithaca, New York (Williams); Erere, Province of Para, Brazil; Urals of Russia.

Lingula stautoniana Rathbun. Middle Devonian.

Lingula stautoniana Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 259, fig. 3.

Loc. Erere, Province of Para, Brazil.

Lingula(?) striata Emmons. Cambrian.

Lingula striata Emmons, American Geology, Pt. II, 1855, p. 112, pl. 1, fig. 17;—Manual Geol., 1860, p. 88, fig. 74.

Loc. Augusta County, Virginia.

Lingula subelliptica d'Orbigny. Clinton (Sil.).

Lingula elliptica Hall (non Phillips), Geol. New York; Rep. Fourth Dist., 1843, p. 76, fig. 7.

Lingula subelliptica d'Orbigny, Prodrome de Pal., I, 1850, p. 34.

Lingula perplexa Hall, Miller's American Pal. Fossils, 1877, p. 244.

Loc. Wolcott, New York.

Lingula submarginata d'Orbigny. Ordovician.

Lingula marginata d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 28, pl. 2, fig. 5.

Lingula submarginata d'Orbigny, Prodrome de Pal., I, 1850, p. 14.

Loc. Tacopaya, Bolivia.

Lingula suboblonga d'Orbigny=L. clintoni.

Lingula subspatulata Meek and Worthen (non Hall and Meek)=Barroisella subspatulata.

Lingula subspatulata Hall and Meek. Upper Cretaceous.

Lingula subspatulata Hall and Meek, Mem. American Acad. Arts Science, n. ser., V, 1854–1856, p. 380, pl. 1, fig. 2.—White, Rep. Geogr. Geol. Survey west 100th Merid., IV, 1875, p. 169, pl. 15, fig. 4.

Lingula subspatulata? Whiteaves, Cont. Canadian Pal., I, 1889, p. 185.

Loc. Near Red Cedar Island, Nebraska; near old Fort Wingate, New Mexico; Rolling River, Manitoba.

Lingula tæniola Hall and Clarke. Clinton (Sil.).

Lingula lamellata Hall (partim), Pal. New York, II, 1852, p. 55, pl. 20, fig. 4.

Lingula tæniola Hall and Clarke, Ibidem, VIII, Pt. I, 1892, pp. 18, 173, pl. 4K, fig. 8.

Loc. Clinton, New York; Hamilton, Ontario.

Lingula thedfordensis Whiteaves. Hamilton (Dev.).

Lingula thedfordensis Whiteaves, Extract Cont. Canadian Pal., I, 1887, p. 3, pl. 15, fig. 1;—Cont. Canadian Pal., I, 1889, p. 111, pl. 15, fig. 1.

Loc. Thedford, Ontario.

Lingula tighti Herrick. Upper Carboniferous.

Lingula tighti Herrick, Bull. Denison Univ., II, 1887, p. 43, pl. 4, fig. 5.

Loc. Newark, Ohio.

Lingula trentonensis Conrad=Glossina trentonensis.

Lingula triangulata Nettelroth=Glossina triangulata.

Digitized by Google

Lingula triquetra Clarke. Portage (Dev.).

Lingula triquetra Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 62, pl. 3, fig. 11.
Loc. Ontario County, New York.

Lingula truncata Sowerby. Neocomian (Cret.).

Lingula truncata Sowerby, Trans. Geol. Soc. London, IV, 1836, pl. 14, fig. 15.—Davidson, British Cret. Brach., Pal. Soc., 1852, p. 6, pl. 1, figs. 27, 28, 31.—Behrendsen, Zeit. der Deutschen Geol. Gesel., XLIV, 1892, p. 27.
Loc. Europe; Arrogo, Trinquico, Argentine Republic.

Lingula umbonata Cox. Upper Carboniferous.

Lingula umbonata Cox, Owen's Geol. Survey Kentucky, III, 1857, p. 576, pl. 10, fig. 4.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 120, pl. 25, fig. 14.—Herrick, Bull. Denison Univ., II, 1887, p. 144, pl. 14, fig. 2.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 226;—Geol. Survey Missouri, V, 1895, p. 38, pl. 35, fig. 4.
Loc. Crittenden, Union, and Hancock counties, Kentucky; Newark, Ohio; Des Moines, Iowa; Clinton and Kansas City, Missouri.

Lingula vanhorni Hall and Clarke (partim)=L. modesta.

Lingula vanhorni Miller. Trenton and Lorraine (Ord.).

Lingula vanhorni Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 9, fig. 1;—Eighteenth Rep. Geol. Survey Indiana, 1894, p. 309.
Lingula procteri Ulrich, American Geologist, III, 1889, p. 377, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 12, pl. 1, figs. 5–7.
Loc. Versailles, Indiana; Covington and Burgin, Kentucky.
Obs. An examination of the type specimen led to the above synonymy.

Lingula varsaviensis Worthen. Warsaw (L. Carb.).

Lingula varsoviense Worthen, Bull. Illinois State Mus. Nat. Hist., 2, 1884, p. 24;—Geol. Survey Illinois, VIII, 1890, p. 104, pl. 11, fig. 8.
Loc. Warsaw and Hamilton, Illinois.

Lingula waverlyensis Herrick=Glossina waverlyensis.

Lingula whitfieldi Ulrich. Lorraine (Ord.).

Lingula whitfieldi Ulrich, American Geologist, III, 1889, p. 381, fig. 3 on p. 378.
Loc. Covington, Kentucky.

Lingula whitei Walcott. Lower Devonian.

Lingula whitii Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 109, pl. 13, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 11, pl. 1, fig. 31.
Loc. Eureka district, Nevada.

Lingula winona Hall=Lingulella winona.

LINGULASMA E. O. Ulrich. Genotype L. schucherti Ulrich.

Lingulasma Ulrich, American Geologist, III, 1889. p. 383.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 24, 46, 163.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 353.—Hall and Clarke, Eleventh Ann. Rep. New York State Geologist, 1894, p. 335.
Lingulelasma Miller, N. American Geol. Pal., 1889, p. 351.

Lingulasma galenaense Winchell and Schuchert. Galena (Ord.).

Lingulasma galenensis Winchell and Schuchert, American Geol., IX, 1892, p. 285;—Minnesota Geol. Survey, III, 1893, p. 354, pl. 30, figs. 1–4.
Loc. Fillmore and Goodhue counties, Minnesota; Decorah, Iowa; Neenah and Oshkosh, Wisconsin.

Digitized by Google

Lingulasma schucherti Ulrich. **Lorraine (Ord.).**

Lingulasma schucherti Ulrich, American Geologist, III, 1889, p. 389, fig. 5 on p. 378.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 24, pl. 2, figs. 17–23.

Lingulelasma schucherti Miller, N. American Geol. Pal., 1889, p. 351.

Loc. Wilmington and Savanna, Illinois.

LINGULELLA Salter. Genotype Lingula davisi McCoy.

Lingulella Salter, Mem. Geol. Survey Great Britain, III, 1866, p. 333.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 55, 163;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 232.

Lingulella affinis Billings=Lingulobolus affinis.

Lingulella ampla (Owen). **Middle Cambrian.**

Lingula ampla Owen, Geol. Rep. Wisconsin, Iowa, and Minnesota, 1852, p. 583, pl. 1B, fig. 5.—Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 125, pl. 6, fig. 10;—Trans. Albany Institute, V, 1867, p. 101.

Loc. Trempealeau, Wisconsin; Winona, Minnesota.

Lingulella aurora Hall. **Upper Cambrian.**

Lingula aurora Hall, Ann. Geol. Rep. Wisconsin, 1861, p. 24;—Geol. Surv. Wisconsin, I, 1862, p. 21, fig. 4; p. 435;—Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 126, pl. 6, figs. 4, 5;—Trans. Albany Institute, V, 1867, p. 103.

Lingulella aurora Hall, Twenty-third Rep. New York State Cab. Nat. Hist., 1873, p. 244.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 2, figs. 12, 13.

Loc. Mazomanie, Wisconsin; Osceola, Wisconsin, and Otisville, Minnesota (Sardeson).

Lingulella(?) billingsana (Whiteaves). **Upper Cambrian.**

Lingula billingsana Whiteaves, American Jour. Sci., 3d ser., XVI, 1878, p. 226.

Lingula cfr. billingsiana Matthew, Trans. Royal Soc. Canada, X, 1894, p. 93, pl. 16, fig. 6.

Loc. Conception Bay, Newfoundland.

Lingulella cælata (Hall). **Lower Cambrian.**

Orbicula cælata Hall, Pal. New York, I, 1847, p. 290, pl. 79, fig. 9.

Obolella cælata Billings, Canadian Nat. Geol., 2d ser., VI, 1871, p. 218.

Obolella (Obolus) cælata Ford, American Jour. Sci., 3d ser., II, 1871, p. 33.

Lingulella cælata Ford, Ibidem, XV, 1878, p. 127.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 95, pl. 7, fig. 1;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 607, pl. 67, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 57, pl. 2, figs. 1–4.

Lingula ? cælata Matthew, Trans. New York Acad. Sci., XIV, 1895, p. 126.

Loc. Troy and Schodack Landing, New York; New Brunswick.

Lingulella cincinnatiensis Hall and Whitfield=Lingula cincinnatiensis.

Lingulella(?) cuneata Matthew. **Lowest Ordovician.**

Lingulella(?) cuneata Matthew, Trans. Royal Soc. Canada, X, 1894, p 92, pl. 16, fig. 5.

Loc. Hardingville, New Brunswick.

Lingulella dawsoni Matthew. **Middle Cambrian.**

Lingula? dawsoni (Matthew MS.) Walcott, Bull. U. S. Geol. Survey, 10, 1884, p. 15, pl. 5, fig. 8.

Lingulella dawsoni Matthew, Trans. Royal Soc. Canada, III, 1886, p. 33, pl. 5, fig. 9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 58, pl. 2, fig. 5.

Loc. Portland, etc., New Brunswick.

Digitized by Google

Lingulella ella (Hall and Whitfield). Lower and Middle Cambrian.

Lingulepis ella Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 232, pl. 1, fig. 8.

Lingulella ella Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 97, pl. 7, fig. 2; pl. 8, fig. 4;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 607, pl. 67, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 58, figs. 19–21.

Loc. Wasatch Range, Utah; near Pioche, Nevada.

Lingulella granvillensis Walcott. Lower Cambrian.

Lingulella granvillensis Walcott, American Jour. Sci., 3d ser., XXXIV, 1887, p. 188, pl. 1, fig. 15;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 607, pl. 67, fig. 4.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 58.

Lingulella cfr. granvillensis Matthew, Trans. New York Acad. Sci., XIV, 1895, p. 114.

Loc. North Granville, New York; ?New Brunswick.

Lingulella(?) inflata Matthew. Middle Cambrian.

Lingulella? inflata Matthew, Trans. Royal Soc. Canada, III, 1886, p. 33, pl. 5, fig. 7;—Trans. New York Acad. Sci., XIV, 1895, p. 127, pl. 5, fig. 3.

Loc. Hanford Brook, St. Martins, New Brunswick.

Lingulella inflata ovalis Matthew. ?Middle Cambrian.

Lingulella inflata var. ovalis Matthew, Trans. New York Acad. Sci., XIV, 1895, p. 127, pl. 5, fig. 4.

Loc. Hanford Brook, New Brunswick.

Lingulella irene (Billings). Upper Cambrian and Calciferous.

Lingula irene Billings, Pal. Fossils, I, 1862, p. 71, fig. 64;—Geol. Canada, 1863, p. 230, fig. 240.

Loc. Point Levis, Canada.

Lingulella lævis Matthew. Upper Cambrian.

Lingulella lævis Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 39, pl. 12, figs. 4a, 4b.

Loc. Near St. John, New Brunswick.

Lingulella lamborni Meek. ?Upper Cambrian.

Lingulella lamborni Meek, Proc. Acad. Nat. Sci. Philadelphia, 1871, p. 185, fig. 1.—Keyes, Geol. Survey Missouri, V, 1895, p. 38, pl. 35, fig. 5.

Loc. Madison County, Missouri.

Lingulella linguloides Matthew. Middle Cambrian.

Lingulella linguloides Matthew, Trans. Royal Soc. Canada, III, 1886, p. 34, pl. 5, fig. 8.

Loc. Porters Brook, St. Martins, New Brunswick.

Lingulella macconelli Walcott. Middle Cambrian.

Lingulella macconelli Walcott, Proc. U. S. Nat. Museum, XI, 1888, p. 441.

Loc. Mt. Stephens, British Columbia.

Lingulella martinensis Matthew. Middle Cambrian.

Lingulella martinensis Matthew, Trans. Royal Soc. Canada, IV, 1890, p. 155, pl. 8, fig. 4;—Trans. New York Acad. Sci., XIV, 1895, p. 113, pl. 2, fig. 6.

Loc. Hanford Brook, New Brunswick.

Lingulella minuta Hall and Whitfield. Up. Camb. and Pogonip (Ord.).

Lingulella? minuta Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 206, pl. 1, figs. 3, 4.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 13.

Loc. Eureka district, Nevada.

Digitized by Google

Lingulella(?) paliformis Hall. Hamilton (Dev.).

Lingula paliformis Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 76, fig. 1.

Lingula palæformis Hall, Pal. New York, IV, 1867, p. 8, pl. 1, fig. 7.—Whitfield, Geol. Wisconsin, IV, 1882, p. 324, pl. 25, fig. 10.

Lingulella? palæformis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 59, 64, pl. 2, figs. 6–8.

Loc. Cayuga Lake, New York; Milwaukee, Wisconsin.

Lingulella radula Matthew. Middle Cambrian.

Lingulella radula Matthew, Trans. Royal Soc. Canada, VIII, 1891, p. 147, pl. 15, figs. 7, 8.

Loc. St. John, New Brunswick.

Lingulella roberti Matthew. Lower Ordovician.

Lingulella roberti Matthew, Trans. Royal Soc. Canada, 2d ser., I, 1896, p. 256, pl. 1, fig. 2.

Loc. Cape Breton, Nova Scotia.

Lingulella selwyni Matthew. Lower Ordovician.

Lingulella selwyni Matthew, Trans. Royal Soc. Canada, 2d ser., I, 1896, p. 255, pl. 1, fig. 1.

Loc. Cape Breton, Nova Scotia.

Lingulella? spissa=Sphærobolus spissus.

Lingulella starri Matthew. Middle Cambrian.

Lingulella starri Matthew, Trans. Royal Soc. Canada, VIII, 1891, p. 146, pl. 15, figs. 5, 6.

Loc. St. Johns, New Brunswick.

Lingulella starri minor Matthew. Upper Cambrian.

Lingulella starri var. minor Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 58.

Loc. Near St. John, New Brunswick.

Lingulella stoneana Whitfield. Upper Cambrian.

Lingula aurora var. Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 127, pl. 6, figs. 6–8;—Trans. Albany Institute, V, 1867, p. 104;—Twenty-third Rep. New York State Cab. Nat. Hist., 1873, pl. 13, fig. 5.

Lingulella stoneana Whitfield, Geol. Wisconsin, IV, 1882, p. 334, pl. 27, figs. 6, 7.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 2, figs. 9–11.

Loc. Prairie du Sac and Mazomanie, Wisconsin.

Lingulella winona (Hall). Middle Cambrian.

Lingula winona Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 126, pl. 6, fig. 9;—Trans. Albany Institute, V, 1867, p. 102.—Sardeson, Bull. Minnesota Acad. Nat. Sci., IV, 1896, p. 96.

Loc. Lansing, Iowa; Wisconsin.

LINGULEPIS Hall. Genotype Lingula pinniformis Owen.

Lingulepis Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 129.—Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 172, 1864, p.1.—Hall, Trans. Albany Institute, V, 1867, p. 106.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 59, 163;—Eleventh Ann. Rep. New York State Geologist, 1894, p. 231.

Obs. The essential difference between Lingulepis and Lingulella is that the ventral beak of the former is often much attenuated. The amount of attenuation, however, is often a very changeable feature in specimens of a species from a locality. It is this variation and the want of large collections that has lead to the making of too many species of Lingulepis.

Digitized by Google

Lingulepis acuminata (Conrad). Upper Cambrian.

Lingula acuminata Conrad, Third. Ann. Rep. New York Geol. Survey, 1839, p. 64.—Hall, Pal. New York, I, 1847, p. 9, with fig.—Billings, Geol. Canada, 1863, p. 102, fig. 8.—Matthew, Trans. Royal Soc. Canada, 2d ser., I, 1896, p. 257, pl. 2, fig. 5.

Lingula antiqua Emmons, Geol. New York; Rep. Second Dist., 1842, p. 268, fig. 68.—Hall, Pal. New York, I, 1847, p. 3, pl. 1, fig. 3.—Emmons, American Geology, Pt. II, 1855, p. 202, pl. 4, fig. 7.

Glossina acuminata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 1, figs. 1, 2.

Loc. Saratoga and Franklin counties, etc., New York; Lansdowne, Bastard, and Beverly, Canada.

Obs. The material of this species in the collection of the U. S. Geological Survey has specimens which are difficult to separate from L. pinniformis and L. dakotensis, and there is every gradation between these and L. acuminata. See L. pinniformis.

Lingulepis acutangulus (Roemer). Upper Cambrian.

Lingula acutangula Roemer, Texas, 1849, p. 420;—Kreidebildung Texas, 1852, p. 90, pl. 11, fig. 10.

Loc. Burnett and Llano counties, Texas.

Lingulepis affinis = Lingulobolus affinis.

Lingulepis cuneolus Whitfield. Upper Cambrian.

Lingulepis cuneolus Whitfield, Powell's Geol. Geogr. Survey Rocky Mountain Region, Prel. Rep., 1877, p. 8;—Ibidem, Final Rep., 1880, p. 336, pl. 2, figs. 5, 6.

Lingulepis perattenuatus Whitfield, Ibidem, Prel. Rep., 1877, p. 9;—Final Rep., 1880, p. 337, pl. 2, figs. 7–9.

Loc. Red Canyon Creek, Black Hills, South Dakota.

Lingulepis dakotensis Meek and Hayden = L. pinniformis.

Lingulepis ella Hall and Whitfield = Lingulella ella.

Lingulepis(?) mæra Hall and Whitfield. Up. Camb. and Pogonip (Ord.).

Lingulepis mæra Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 206, pl. 1, figs. 5–7.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 12.

Lingulepis? mæra Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 61.

Loc. Secret Canyon, Ruby Hill, and Eureka district, Nevada.

Lingulepis matinalis Hall. Upper Cambrian.

Lingulepis pinnaformis Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 130;—Ibidem, 1863, p. 130, pl. 6, figs. 12, 13.

Obs. A distinct species occurring in numbers in a blue shale just above the trap at St. Croix Falls, Wisconsin.

Lingulepis minima Whitfield = L. prima.

Lingulepis minuta Hall and Whitfield = Obolella whitfieldi.

Lingulepis morsensis N. H. Winchell = Lingula morsei.

Lingulepis perattenuata Whitfield = L. cuneolus.

Lingulepis pinniformis (Owen). Upper Cambrian.

Lingula antiqua and prima (non Emmons, Hall, 1847) Foster and Whitney, Geol. Rep. Lake Superior Dist., II, 1851, p. 204, pl. 23, figs. 1, 2.—Hall, Geol. Wisconsin, I, 1862, p. 21, fig. 3.—Hayden, American Jour. Sci., 2d ser., XXXIII, 1863, p. 73.

Lingula pinnaformis Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, p. 583, pl. 1B, figs. 4, 6, 8.—Hall, Geol. Wisconsin, I, 1862, pp. 21, 435, fig. 3.

Digitized by Google

Lingulepis pinniformis (Owen)—Continued.

Orbicula prima Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, figs. 17, 19.

Lingulepis pinnaformis Hall, Sixteenth Rep. New York State Cab. Nat. Hist., 1863, p. 129, pl. 6, figs. 14–16;—Trans. Albany Institute, V, 1867, p. 107.—Whitfield, Powell's Geol. Geogr. Survey Rocky Mountain Region, 1880, p. 335, pl. 2, figs. 1–4;—Geol. Wisconsin, IV, 1882, p. 169, pl. 1, figs. 2, 3.

Lingulepis pinniformis and dakotensis Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 172, 1864, pp. 2, 3, pl. 1, fig. 1.

Lingulepis dakotensis Whitfield, Powell's Geol. Geogr. Survey Rocky Mountain Region, 1880, p. 337, pl. 2, figs. 10, 11.

Lingulepis pinniformis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 60, figs. 22, 23; pl. 1, figs. 35, 36.

Loc. Falls of St. Croix, Hudson, etc., Wisconsin; Black Hills, South Dakota.

Obs. This species also occurs at Ausable Chasm and Whitehall, New York, and are there regarded as L. acuminata. It may be advisable to refer Owen's species to L. acuminata (Conrad).

Lingulepis prima Meek and Hayden=Obolella polita.

Lingulepis prima (Hall). Upper Cambrian.

Lingula ovata Emmons, Geol. New York; Rep. Second Dist., 1842, p. 105 (undefined).

Lingula prima (Conrad MS.) Hall, Pal. New York, I, 1847, p. 3, pl. 1, fig. 2.—Emmons, American Geology, Pt. II, 1855, p. 202.

Obolella prima Whitfield, Bull. American Mus. Nat. Hist., I, 1884, p. 142, pl. 14, figs. 3–5.

Lingulepis minima Whitfield, Ibidem, 1884, p. 141, pl. 14, figs. 1, 2.

Lingulella? prima Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 69.

Loc. Keeseville, Essex, etc., New York; ?Black Hills, South Dakota.

Lingulepis primiformis Whitfield. Upper Cambrian.

Lingulepis primæformis Whitfield, Ludlow's Rep. Reconn. Black Hills South Dakota, 1875, p. 103, pl. 1, fig. 4.

Loc. Black Hills, South Dakota.

LINGULOBOLUS Matthew. Genotype Lingulella(?) affinis Billings.

Lingulobolus Matthew, Trans. Royal Soc. Canada, 2d ser., I, 1896, p. 260.

Lingulobolus affinis (Billings). Lower Ordovician.

Lingulella? affinis Billings, Canadian Nat. Geol., n. ser., VI, 1872, p. 468, fig. 4;—Pal. Fossils, II, 1874, p. 67, fig. 35.

Lingulepis affinis Walcott, American Jour. Sci., 3d ser., XXXVII, 1889, p. 381.

Lingulobolus affinis Matthew, Trans. Royal Soc. Canada, 2d ser., I., 1896, p. 261, pl. 1, fig. 4.

Loc. Bell Island, Newfoundland.

Lingulobolus affinis cuneata Matthew. Lower Ordovician.

Lingulobolus affinis var. cuneata Matthew, Trans. Royal Soc. Canada, 2d ser., I, 1896, p. 262, pl. 1, figs. 4e, 4d.

Loc. Great Bell Island, Conception Bay, Newfoundland.

LINGULODISCINA Whitfield. Genotype Lingula exilis Hall.

Lingulodiscina Whitfield, Bull. American Mus. Nat. Hist., III, 1890, p. 122, figs. 1–8.

Œhlertella Hall and Clarke, Pal. New York, VIII, Pt. I, 1890, pp. 133, 168;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 257.

Lingulodiscina(?) connata (Walcott). Lower Carboniferous.

Discina connata Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 214, pl. 7, fig. 3.

Loc. Eureka district, Nevada.

Digitized by Google

Lingulodiscina exilis (Hall). Marcellus (Dev.).

Lingula exilis Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 77, fig. 2;—Pal. New York, IV, 1867, p. 7, pl. 1, figs. 8, 9.

Lingulodiscina exilis Whitfield, Bull. American Mus. Nat. Hist., III, 1890, p. 122, figs. 1–8.

Loc. Schoharie County, New York.

Lingulodiscina newberryi (Hall). Waverly (L. Carb.).

Discina newberryi Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 30;—Pal. New York, IV, 1867, p. 25, pl. 1, figs. 10, 11.

Discina (Orbiculoidea) newberryi Meek, Pal. Ohio, II, 1875, p. 277, pl. 14, fig. 1.

Discina newberryi Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 213, pl. 18, fig. 3.—Keyes, Geol. Survey Missouri, V, 1895, p. 40.

Orbiculoidea newberryi Herrick, Bull. Denison Univ., IV, 1888, p. 12;—Geol. Ohio, VII, 1895, pl. 22, figs. 11, 13.

Œhlertella newberryi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 132, pl. 4F, fig. 18.

Loc. Cuyahoga Falls, Akron, and Farmington, Ohio; Eureka district, Nevada.

Obs. This species should be compared with Orbiculoidea(?) capax (White.)

Lingulodiscina pleurites (Meek). Waverly (L. Carb.).

Discina (Orbiculoidea?) pleurites Meek, Pal. Ohio, II, 1875, p. 278, pl. 14, fig. 2.

Orbiculoidea pleurites Herrick, Bull. Denison Univ., IV, 1888, pp. 12, 19, pl. 3, fig. 5;—Geol. Ohio, VII, 1895, pl. 22, fig. 12.

Œhlertella pleurites Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 132, pl. 4E, figs. 21–24; pl. 4F, figs. 19, 20.

Loc. Newark and Gann, Knox County, Ohio.

LINGULOPS Hall. Genotype L. whitfieldi Hall.

Lingulops Hall, Notes on some New or Imperfectly Known Forms among the Brachiopoda, 1871, p. 2;—Ibidem, 1872, p. 2, pl. 13, figs. 1, 2;—Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, p. 244, pl. 13, figs. 1, 2.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 164.—Hall and Clarke, Pal. New York, VIII, Pt. 1, 1892, pp. 18, 46, 163;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 233.

Lingulops granti Hall and Clarke. Niagara (Sil.).

Lingulops granti Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 19, 173, pl. 4K, figs. 14, 15.

Loc. Hamilton, Ontario.

Lingulops norwoodi (James). Utica (Ord.).

Lingula norwoodi James, Cincinnati Quart. Jour. Sci., II, 1875, p. 10, fig. 2;—Jour. Cincinnati Soc. Nat. Hist., VI, 1883, p. 235, pl. 10, fig. 1.

Lingulops norwoodi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 19, pl. 2, figs. 24–26.

Loc. Covington, Kentucky.

Lingulops whitfieldi Hall. Maquoketa (Ord.).

Lingulops whitfieldi Hall, Notes on some New or Imperfectly Known Forms among the Brachiopoda, 1872, p. 2, pl. 13, fig. 12;—Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, pl. 13, figs. 1, 2.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 164, pl. 19, fig. 9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 19, pl. 2, figs. 27–30.

Loc. Near Lattners, Dubuque County, Iowa.

LINNARSSONIA Walcott. Genotype Obolella transversa Hartt.

Linnarssonia Walcott, American Jour. Sci., 3d ser., XXIX, 1885, p. 115; XXX, p. 21.—Matthew, Trans. Royal Soc. Canada, III, 1886, p. 35.—Hall and

Digitized by Google

LINNARSSONIA Walcott—Continued.

Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 107, 167;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 251.—Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 42.

Linnarssonia belti Davidson. Upper Cambrian.

Linnarssonia belti ? Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 42, pl. 12, figs. 7a–7c.

Loc. Near St. John, New Brunswick.

Linnarssonia misera (Billings). Middle Cambrian.

Obolella? misera Billings, Canadian Nat. Geol., n. ser., VI, 1872, p. 470.

Linnarssonia misera Matthew, Trans. Royal Soc. Canada, III, 1886, p. 35, fig. 12.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 108, pl. 8, figs. 35–37.

Loc. Trinity Bay, Newfoundland; St. Martins, New Brunswick.

Linnarssonia pretiosa (Billings). Upper Cambrian.

Obolella pretiosa Billings, Pal. Fossils, I, 1862, p. 68, fig. 61;—Geol. Canada, 1863, p. 230, fig. 239.

Obolella? pretiosa Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 111.

Linnarssonia pretiosa Dawson, Trans. Royal Soc. Canada, VII, 1889, p. 53, fig. 26.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 70, pl. 3, figs. 43, 44.

Loc. Bridge of the Grand Trunk Railroad across the Chaudiere River; Cape Rouge; Little Metis; Sillery and Point Levis, Canada.

Linnarssonia sagittalis taconica Walcott. Lower and Middle Cambrian.

Linnarssonia taconica Walcott, American Jour. Sci., 3d ser., XXXIV, 1887, p. 189. pl. 1, fig. 18.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 106.

Linnarssonia sagittalis Walcott, Proc. U. S. Nat. Mus., XI, 1888, p. 442.

Linnarssonia sagittalis var. taconica Walcott, American Jour. Sci., 3d ser., XXXVIII, 1889, p. 36;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 610, pl. 68, fig. 1.

Loc. Washington County, New York; Mount Stephan, British Columbia.

Linnarssonia taconica Walcott=L. sagittalis taconica.

Linnarsonia transversa (Hartt). Middle Cambrian.

Obolella transversa Hartt, Dawson, Acadian Geol., 2d ed., 1868, p. 644.—Walcott, Bull. U. S. Geol. Survey, 10, 1884, p. 16, pl. 1, fig. 5.

Linnarssonia transversa Walcott, American Jour. Sci., 3d ser., XXIX, 1885, p. 116, figs. 3, 4, 6.—Matthew, Trans. Royal Soc. Canada, III, 1886, p. 35, pl. 5, fig. 11.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 108, pl. 3, figs. 38–42.—Matthew, Trans. N. Y. Acad. Sci., XIV, 1895, p. 125, pl. 5, figs. 1, 2.

Loc. St. John, New Brunswick.

LISSOPLEURA Whitfield. Genotype Rhynchonella æquivalvis Hall.

Lissopleura Whitfield, Bull. Am. Mus. Nat. Hist., VIII, 1896, p. 232.

Lissopleura æquivalvis (Hall). Lower Helderberg (Dev.).

Rhynchonella æquivalvis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 66;—Pal. New York, III, 1859, p. 224, pl. 29, pp. 2, 3.

Lissopleura æquivalvis Whitfield, Bull. Am. Mus. Nat. Hist., VIII, 1896, p. 232. figs. 1–5.

Loc. Helderberg Mountains, New York.

MARTINIA McCoy. Genotype Anomites glabra Martin.

Martinia McCoy, Carboniferous Fossils Ireland, 1844, p. 128, fig. 18; p. 139, fig. 132.—King, Mon. Permian Fossils, Pal. Soc., 1850, pp. 81, 134.—Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 172, 1864, p. 19.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 528.—Herrick, Bull. Denison Univ., IV, 1888, p. 14.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 9, 32, 40.

Digitized by Google

Martinia athyroides A. Winchell. Hamilton (Dev.).

Martinia athyroides A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 94.
Loc. Grand Traverse region, Michigan.

Martinia glabra (Martin). Upper Carboniferous.

Anomites glabra Martin, Petrefacta Derbiensia, 1809, pl. 48, figs. 9, 10.
Spirifera glabra Davidson, Quart. Jour. Geol. Soc. London, XIX, 1863, p. 170, pl. 9, figs. 9, 10.—Dawson, Acadian Geology, 3d ed., 1878, p. 291, fig. 89.
Loc. Europe; Pictou, Windsor, etc., Nova Scotia.

Martinia glabra contracta (Meek and Worthen). Kaskaskia (L. Carb.).

Spirifera glabra var. contracta Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 143;—Geol. Survey Illinois, II, 1866, p. 298, pl. 23, fig. 5.—White, Wheeler's Expl. Survey west 100th Merid., IV, 1875, p. 136, pl. 10, fig. 2.
Spirifera (Martinia) contractus Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 583, pl. 13, figs. 17–19.
Spirifera (Martinia) contracta Whitfield, Geol. Ohio, VII, 1895, p. 471, pl. 9, figs. 17–19.
Loc. Chester, Illinois; Newtonville, Ohio; Lincoln County, Nevada.

Martinia glanscerasi (White). Hamilton (Dev.).

Spirifera glanscerasi White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 24.
Loc. Iowa City, Iowa.

Martinia(?) insolita A. Winchell. Huron (Dev.).

Spirifera? insolita A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 406.
Loc. Port aux Barques, Michigan.

Martinia lævigata (Swallow). Keokuk (L. Carb.).

Spirifera lævigata Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 86.
Loc. Iowa and Missouri.
Obs. Regarded by Keyes as a synonym for Spirifer logani.

Martinia maia (Billings). Corniferous (Dev.).

Athyris maia Billings, Canadian Jour. Sci., V, 1860, p. 276, figs. 33, 34;—Geol. Canada, 1863, p. 373, fig. 398.
Athyris? maia Nicholson, Pal. Prov. Ontario, 1874, p. 88.
Spirifera maia Hall, Pal. New York, IV, 1867, p. 146, pl. 63, figs. 6–13.—Davidson, Suppl. British Sil. Brach., Paleontographical Soc., 1882, p. 122.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 549, pl. 11, fig. 14.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 38, figs. 5, 6.—Whitfield, Geol. Ohio, VII, 1895, p. 444, pl. 7, fig. 14.
Spirifera (Martinia) maia Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 141, pl. 14, fig. 13 (?pl. 3, fig. 1).
Loc. St. Marys, Township of Blanchard, Ontario; Columbus and Delaware, Ohio; Eureka district, Nevada.

Martinia meristoides Meek. Middle Devonian.

Spirifera (Martinia) meristoides Meek, Trans. Chicago Acad. Sci, I, 1868, p. 106, pl. 14, fig. 3.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 142.—Whiteaves, Cont. Canadian Pal., I, 1891, p. 226.
Loc. Mackenzie River Basin, British America.

Martinia planoconvexa Meek and Hayden=Ambocœlia planiconvexa.

Martinia sublineata Meek. Middle Devonian.

Spirifera (Martinia) sublineata Meek, Trans. Chicago Acad. Sci., I, 1868, p. 103, pl. 14, fig. 1.
Loc. Great Slave Lake, British America.

Digitized by Google

Martinia subumbona (Hall). Hamilton-Portage (Dev.).

Orthis subumbona Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 168.

Ambocœlia subumbona Hall, Thirteenth Rep. Ibidem, 1860, p. 71.

Spirifera subumbona Hall, Pal. New York, IV, 1867, p. 234, pl. 33, figs. 22–30.

Martinia subumbona Miller, N. American Geol. Pal., 1889, p. 352.

Spirifer subumbona Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 29, fig. 14.

Loc. Shore of Lake Erie, Tully, and McKinneys Station, New York.

Obs. Professor Williams says this species is a synonym for Ambocœlia gregaria.

MEEKELLA White and St. J. Genotype Plicatula striatocostata Cox.

Meekella White and St. John, Trans. Chicago Acad. Sci., I, 1868, p. 120, figs. 4–6.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 175.—Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 576.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 264;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 287.

Meekella occidentalis (Newberry). Upper Carboniferous.

Streptorhynchus occidentalis Newberry, Ives's Rep. Colorado River of the West, 1861, p. 126, pl. 1, fig. 5.

Meekella occidentalis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 266, pl. 11B, figs. 18, 19.

Loc. Canyon of Cascade River.

Obs. See Meekella pyramidalis.

Meekella(?) occidentalis (Swallow). Upper Carboniferous.

Orthisina occidentalis Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 82.

Loc. Caldwell County, Missouri.

Obs. If a Meekella it should be compared with M. striaticostata. Regarded by Keyes as a synonym for M. striaticostata.

Meekella pyramidalis (Newberry). Upper Carboniferous.

Streptorhynchus pyramidalis Newberry, Ives's Rep. Colorado River of the West, 1861, p. 126, pl. 2, figs. 11–13.

Meekella pyramidalis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 266.

Loc. Colorado River.

Obs. This species is quite distinct from M. striaticostata Cox, with which it has been confounded. M. occidentalis Newberry, however, may prove to be but a large individual of M. pyramidalis.

Meekella striaticostata (Cox). Upper Carboniferous.

Plicatula striatocostata Cox, Owen's Geol. Survey Kentucky, III, 1857, p. 568, pl. 8, fig. 7.

Orthisina shumardianus Swallow, Trans. St. Louis Acad. Sci., I, 1858, p. 183.

Orthisina missouriensis Swallow, Ibidem, 1858, p. 219.—Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, III, 1859, p. 26.

Orthisina shumardiana Meek and Hayden, Ibidem, 1859, p. 26.

Orthis striatocosta Geinitz, Carbon und Dyas in Nebraska, 1866, p. 48, pl. 3, figs. 22–24.

Meekella striatocostata White and St. John, Trans. Chicago Acad. Sci., I, 1868, pp. 120, 122, figs. 4–6.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 175, pl. 5, fig. 12.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 571, pl. 26, fig. 21.—White, Wheeler's Expl. Survey west 100th Merid., IV, 1875, p. 26, pl. 9, fig. 4.—Kayser, Richthofen's China, IV, 1883, p. 178, pl. 23, fig. 8.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 130, pl. 26, figs. 12–14.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 265, pl. 10, figs. 18–23; pl. 11B, figs. 20–22.—Keyes, Geol. Survey Missouri, V, 1895, p. 68, pl. 39, fig. 1.

Digitized by Google

Meekella striaticostata (Cox)—Continued.

Streptorhynchus (Meekella) striatocostata Hall, Second Ann. Rep. New York State Geol., 1883, pl. 40, figs. 18–23.

Loc. Hopkins County, Kentucky; Indiana; Illinois; Missouri; Iowa; Nebraska; New Mexico; Nevada; Utah; ?China.

Obs. See M. occidentalis (Swallow).

MEGALANTERIS Œhlert. Genotype Terebratula archiaci de Verneuil.

Meganteris Suess, Sitz. der k. k. Akad. der Wissensch. zu Wien, XVIII, 1855, p. 51.

Megalanteris Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1319.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 277;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 859.

Megalanteris condoni (McChesney). Oriskany (Dev.).

Rensselæria condoni McChesney, New Pal. Fossils, 1861, p. 85;—Trans. Chicago Acad. Sci., I, 1868, p. 36, pl. 7, fig. 2.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 401, pl. 8, fig. 4.

Newberria? condoni Hall, Tenth Ann. Rep. N. Y. State Geol., 1891, p. 7 of extract.

Megalanteris condoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 280.

Loc. West of Jonesboro, Union County, Illinois.

Megalanteris ovalis Hall. Oriskany (Dev.).

Meganteris ovalis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 101.

Rensselæria ovalis Hall, Pal. N. Y., III, 1859, p. 458, pl. 106, fig. 2.—Billings, Geol. Canada, 1863, p. 962, fig. 471.

Megalanteris ovalis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 280, pl. 77, figs. 12–22.

Loc. Albany and Schoharie counties, New York.

Meganteris æquiradiata Hall=Rensselæria æquiradiata.

Meganteris cumberlandiæ Hall=Rensselæria cumberlandiæ.

Meganteris elliptica Hall=Rensselæria elliptica.

Meganteris elongata Hall=Amphigenia elongata.

Meganteris lævis Hall=Meristella lævis.

Meganteris mutabilis Hall=Rensselæria mutabilis.

Meganteris ovalis Hall=Megalanteris ovalis.

Meganteris ovoides Hall=Rensselæria ovoides.

Meganteris subtrigonalis Hall=Amphigenia elongata subtrigonalis.

Meganteris suessana Hall=Beachia suessana.

Megerlia dubitanda Cooper=Terebratella(?) dubitanda.

MERISTA Suess. Genotype Atrypa herculea Barrande.

Merista Suess, Jahrbuch Köngl. Kais. Geol. Reichs., II, 1851, pp. 150, 160.—Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 73;—Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 258.—Dall, Bull. U. S. Nat. Mus., 8, 1877, p. 47.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 70, fig. 54;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 771.

Camarium Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 42;—Pal. New York, III, 1859, p. 486;—Fifteenth Rep. N. Y. State Cab. Nat. Hist., 1862, p. 176.

Merista arcuata Hall=Meristella arcuata.

Merista bella Hall=Meristella bella.

Merista bisulcata Hall=Whitfieldella bisulcata.

Merista crassirostra Hall=Whitfieldella cylindrica.

Merista cylindrica Hall=Whitfieldella cylindrica.

Digitized by Google

Merista elongata (Hall). Lower Helderberg (Dev.).

Camarium elongatum Hall, Pal. New York, III, 1859, p. 488, pl. 95A, fig. 4.

Loc. Cumberland, Maryland.

Obs. Probably only a variety of M. typa.

Merista houghtoni Winchell=Meristella houghtoni.

Merista lævis Hall=Meristella lævis.

Merista lata Hall=Meristella lata.

Merista lens Hall=Meristella lens.

Merista meeki Hall=Meristella meeki.

Merista princeps Hall=Meristella princeps.

Merista subquadrata Hall=Meristella subquadrata.

Merista tennesseensis Hall and Clarke. Lower Helderberg (Dev.).

Merista tennesseensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. 71, 365, pl. 42, figs. 1–6.

Loc. Perry County, Tennessee.

Merista typus Hall. Lower Helderberg (Dev.).

Camarium typum Hall, Pal. New York, III, 1859, p. 487, pl. 95A, figs. 2a, 3, 5, 6.

Merista typum Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 93, figs. 10–13.

Merista typa Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 42, figs. 7–12.

Loc. Cumberland, Maryland.

MERISTELLA Hall, 1860. Genotype Merista arcuata Hall.

?Meristella Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.

Meristella Hall, Thirteenth Rep. Ibidem, 1860, pp. 74, 93;—Sixteenth Rep. Ibidem, 1863, p. 50, figs. 27–34;—Trans. Albany Institute, IV, 1863, p. 139;—American Jour. Sci., 2d ser., XXXV, 1863, p. 396; XXXVI, p. 11;—Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, pp. 155, 258;—Pal. New York, IV, 1867, p. 295.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 97.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 73, figs. 55, 56;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 773.

Athyris Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 115.

Meristella arcuata Hall. Lower Helderberg (Dev.).

Merista arcuata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 95, figs. 1–4;—Pal. New York, III, 1859, p. 249, pl. 41, fig. 1 (?2).

Meristella arcuata Hall, Ibidem, IV, 1867, p. 298, figs. 1, 2.—Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 43, figs. 1, 2; pl 44, fig. 5.

Loc. Albany and Schoharie counties, New York; St. Blandine, New Brunswick.

Meristella barrisi Hall. Marcellus-Hamilton (Dev.).

Meristella barrisi Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 84;—Pal. New York, IV, 1867, p. 304, pl. 49, figs. 5–22.—?Tschernyschew, Mémoires du Comité Géologique de St. Pétersbourg, III, 3, 1887, p. 55, pl. 9, figs. 12, 15; pl. 13, figs. 1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 43, figs. 25, 26; pl. 44, figs. 27–30.

Loc. York and Leroy, New York; Urals of Russia.

Meristella bella (Hall). Lower Helderberg (Dev.).

Merista bella Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 92, figs. 1–7;—Pal. New York, III, 1859, p. 248, pl. 40, fig. 1.

Meristella bella Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 510, pl. 5, figs. 8–10.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 43, figs. 7–9; pl. 44, figs. 1–3.—Whitfield, Geol. Ohio, VII, 1895, p. 412, pl. 1, figs. 8–10.

Loc. Albany and Schoharie counties, New York; Greenfield, Ohio; Lake Temiscouata, New Brunswick.

Digitized by Google

Meristella(?) blancha (Billings). Lower Helderberg (Dev.).

Athyris blancha Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 115, pl. 3, fig. 13.

Meristina (?) blancha Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 68, pl. 41, figs. 22, 23.

Loc. Square Lake, Maine.

Obs. Compare with Meristella arcuata.

Meristella clusia (Billings). Corniferous (Dev.).

Athyris? clusia Billings, Canadian Jour. Sci., V, 1860, p. 279.

Loc. Cayuga, Ontario.

Meristella doris Hall. Upper Helderberg (Dev.).

Meristella doris Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 84;—Pal. New York, IV, 1867, p. 303, pl. 50, figs. 1–12.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 43, figs. 21, 22.

Charionella doris Billings, Geol. Canada, 1863, p. 374, figs. 400E, 401a, b.

Loc. Schoharie and Williamsville, New York; Cayuga, Ontario.

Meristella elissa Hall=Meristella nasuta.

Meristella haskinsi Hall. Hamilton (Dev.).

Meristella haskinsi Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 84;—Pal. New York, IV, 1867, p. 306, pl. 49, figs. 23–35.—Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 43, figs. 23, 24; pl. 44, fig. 31.

Loc. Seneca Lake, York, Moscow, etc., New York; Thedford, Ontario.

Meristella (?) houghtoni (A. Winchell). Huron (Dev.).

Merista houghtoni Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 407.

Meristella (?) houghtoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 78.

Loc. Port aux Barques, Michigan.

Meristella (?) incerta Simpson. Waverly (L. Carb.).

Meristella incerta Simpson, Trans. American Philosophical Soc., n. ser., XVI, 1889, p. 442, fig. 7.

Loc. Warren, Pennsylvania.

Obs. Based upon a crushed and broken specimen.

Meristella lævis (Vanuxem). Lower Helderberg (Dev.).

Atrypa lævis Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 120, fig. 2.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 825, fig. 642.

Merista lævis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 94, figs. 1–6;—Pal. New York, III, 1859, p. 247, pl. 39, figs. 3, 4.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 376, pl. 7, fig. 8.

Meristella lævis Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 510, pl. 5, figs. 6, 7.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 43, figs. 3–6; pl. 44, fig. 4.—Whitfield, Geol. Ohio, VII, 1895, p. 411, pl. 1, figs. 6, 7.

Loc. Albany and Schoharie counties, New York; Greenfield, Ohio; Perry County, Missouri; Pennsylvania; Square Lake, Maine; St. Blandine, New Brunswick.

Meristella (?) lævis (Hall). Lower Helderberg (Dev.).

Meganteris lævis Hall (non Vanuxem), Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 99.

Rensselæria lævis Hall, Pal. New York, III, 1859, p. 256, pl. 40, fig. 2.

Loc. Albany County, New York.

Meristella lata Hall. Oriskany (Dev.).

Merista lata Hall, Pal. New York, III, 1859, p. 431, pl. 101, fig. 3.

Meristella lata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 78, pl. 44, fig. 12.

Loc. Albany and Schoharie counties, New York; Cayuga, Ontario.

Digitized by Google

Meristella lens (A. Winchell). Hamilton (Dev.).

Merista lens A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 94.

Meristella lens Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 78.

Loc. Grand Traverse region, Michigan.

Meristella lenta Hall. Oriskany (Dev.).

Meristella lenta Hall, Pal. New York, IV, 1867, p. 420, pl. 63, figs. 19–22.—Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 44, figs. 15–18.

Loc. Cayuga, Ontario.

Meristella maria Hall=Meristina maria.

Meristella meeki Hall. Lower Helderberg (Dev.).

Merista meeki Hall, Tenth Rep. N. Y. State Cab. Nat. Hist, 1857, p. 97;—Pal. New York, III, 1859, p. 252, pl. 44, fig. 6.

Camarium meeki Hall, Ibidem, III, 1859, p. 486.

Meristella meeki Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 78.

Loc. Perry County, Tennessee.

Meristella meta Hall. Hamilton (Dev.).

Meristella meta Hall, Pal. New York, IV, 1867, p. 308, pl. 49, figs. 1–4.—Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 43, figs. 29, 30.

Loc. Delphi, New York.

Meristella nasuta (Conrad). Upper Helderberg (Dev.).

Atrypa nasuta Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 265.

Terebratula valenciennii Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 39, pl. 13, fig. 6.

Meristella nasuta Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 93, figs. 8, 9;—Fifteenth Rep. Ibidem, 1862, p. 160, figs. 17–22 on p. 161;—Pal. New York, IV, 1867, p. 299, pl. 48, figs. 1–25.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 98, pl. 15, figs. 2–8.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 43, figs. 18–20; pl. 44, figs. 13, 14, 19–26.

Athyris clara Billings, Canadian Jour. Sci., V, 1860, p. 274, figs. 29–32;—Geol. Canada, 1863, p. 373, fig. 397;—Canadian Nat. Geol., n. ser., VII, 1874, p. 240.

Meristella elissa Hall, Fourteenth Rep. N. Y. State Cab. Nat. Hist., 1861, p. 100;—Fifteenth Rep. Ibidem, 1862, pl. 3, figs. 21, 22.

Athyris nasuta Nicholson, Pal. Prov. Ontario, 1874, p 86.

Meristella (Whitfieldia) nasuta Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 148, pl. 3, fig. 8.

Loc. Schoharie, Clarence, Williamsville, etc., New York; Cayuga, Ontario; Columbus and Dublin, Ohio; Falls of Ohio; Lone Mountain, Nevada.

Meristella nucleolata Whitfield=Whitfieldella nucleolata.

Meristella princeps Hall. Lower Helderberg (Dev.).

Merista princeps Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 95, figs. 1–5;—Pal. New York, III, 1859, p. 251, pl. 44, figs 1–5.

Camarium princeps Hall, Ibidem, III, 1859, p. 486.

Meristella princeps Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 93, figs. 5–7.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 43, figs. 10–13.

Loc. Carlisle and Schoharie, New York; St. Blandine, New Brunswick.

Meristella rectirostra Hall=Meristina rectirostris.

Meristella riskowskyi A. Ulrich. Middle Devonian.

Meristella riskowskyi A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 64, pl. 4, figs. 16–18.

Loc. Chahuarani and near Oconi, Bolivia.

Digitized by Google

Meristella rostrata Hall. Hamilton (Dev.).

Atrypa rostrata Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 202, fig. 2.
Athyris? rostrata Billings, Canadian Jour. Sci., V, 1860, p. 281, figs. 43, 44.
Charionella rostrata Billings, Geol. Canada, 1863, p. 385, fig. 420.
Meristella rostrata Hall, Pal. New York, IV, 1867, p. 307, pl. 50, figs. 13–17.—Hall and Clarke, Ibidem, Vol. VIII, Pt. II, 1895, pl. 43, figs. 27, 28.
Loc. Eighteen Mile Creek, etc., New York; Bosanquet, Ontario.

Meristella subquadrata Hall. Lower Helderberg (Dev.)

Merista subquadrata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 93;—Pal. New York, III, 1859, p. 249, pl. 40, fig. 3.
Meristella subquadrata Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 78, pl. 43, figs. 14, 15.
Loc. Schoharie and Carlisle, New York.

Meristella unisulcata Hall = Pentagonia unisulcata.

Meristella unisulcata biplicata Hall = Pentagonia unisulcata biplicata.

Meristella unisulcata uniplicata Hall = Pentagonia unisulcata uniplicata.

Meristella walcotti Hall and Clarke. Oriskany (Dev.).

Meristella walcotti Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. 77, 365, figs. 55, 56, pl. 43, figs. 16, 17; pl. 44, figs. 6–11, 23, 32.
Loc. Cayuga, Ontario.

MERISTINA Hall. Genotype Meristella maria Hall.

Meristina Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 157;—Pal. New York, IV, 1867, p. 299.—Nettelroth (partim), Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 101.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 65;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 770.
Whitfieldia Davidson, Supplement British Sil. Brach., Paleontographical Soc., 1882, p. 107.—Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 73.

Meristina maria Hall. Niagara (Sil.).

Athyris tumida Roemer, Sil. Fauna west. Tennessee, 1860, p. 70, pl. 5, fig. 12.
Meristella maria Hall, Trans. Albany Institute, IV, 1863, p. 212.—Hall and Whitfield, Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 196.
Meristina maria Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 157;—Pal. New York, IV, 1867, p. 299.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 132, pl. 7, figs. 5, 6.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 101, pl. 29, figs. 7–10.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 67, pl. 41, figs. 1–17.
Meristella tumida Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 597.
Meristella (Meristina) maria Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 159, pl. 25, figs. 8–12;—Eleventh Rep. State Geol. Indiana, 1882, p. 299, pl. 25, figs. 8–12.
Whitfieldia maria Beecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 73, pl. 7, figs. 1–3.
Loc. Waldron, Indiana; Springfield, Ohio; Louisville, Kentucky; Perry County, Tennessee; Bridgeport, Illinois; Racine, Wisconsin; Bessels Bay, 81° 6′.
Obs. This species is not identical with M. tumida Dalman.

Meristina nitida Hall = Whitfieldella nitida.

Meristina rectirostris Hall. Niagara (Sil.).

Meristella rectirostra Hall, Descriptions n. sp. Fossils from Waldron, Indiana, 1879, p. 15;—Eleventh Rep. State Geol. Indiana, 1882, p. 301, pl. 27, figs. 10–14;—Trans. Albany Institute, X, 1883, p. 71.—Beecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 67, pl. 7, figs. 4, 5, 11–13.

Digitized by Google

Meristina rectirostris Hall—Continued.

Meristina rectirostra Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 68, figs. 52, 53, pl. 41, figs. 18–21.

Loc. Waldron, Indiana.

Meristina trisinuata (McChesney). Niagara (Sil.).

Pentamerus trisinuatus McChesney, Descriptions New Pal. Fossils, 1861, p. 86.

Athyris? trisinuatus McChesney, Trans. Chicago Acad. Sci., I, 1868, p. 33, pl. 8, fig. 2.

Loc. Milwaukee, Wisconsin.

Obs. Probably synonymous with Meristina maria.

METAPLASIA Hall and Clarke. Genotype Spirifer pyxidata Hall.

Metaplasia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 56;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 762.

Metaplasia disparilis (Hall). Corniferous (Dev.).

Spirifer disparilis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 134.

Spirifera disparilis Hall, Pal. New York, IV, 1867, p. 204, pl. 30, figs. 10–15.

Metaplasia pyxidata Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 39, figs. 19–22.

Loc. Williamsville and Clarence Hollow, New York.

Metaplasia pyxidata Hall. Oriskany (Dev.).

Spirifer pyxidata Hall, Pal. New York, III, 1859, p. 428, pl. 100, figs. 9–12.

Metaplasia pyxidata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 56.

Loc. Albany and Schoharie counties, New York; Cumberland, Maryland; Cayuga, Ontario.

Micromitra Meek=Iphidea.

MIMULUS Barrande. Genotype M. perversus Barrande.

Mimulus Barrande, Système Silurien du Centre de la Bohème, V, 1879, p. 109.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 272;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 289.

Mimulus waldronensis (Miller and Dyer). Niagara (Sil.).

Spirifera (?) waldronensis Miller and Dyer, Jour. Cincinnati Soc. Nat. Hist., I, 1878, p. 37, pl. 2, fig. 3.

Triplesia putillus Hall, Descriptions n. sp. Fossils Waldron, Indiana, 1879, p. 16;—Eleventh Rep. State Geol. Indiana, 1882, p. 298, pl. 27, figs. 19–22;—Trans. Albany Institute, X, 1883, p. 72.

Streptis waldronensis Beecher and Clarke, Mem. New York State Mus., I, 1889, p. 30, pl. 3, figs. 9, 10.

Mimulus waldronensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 273, pl. 11C, figs. 23–28.

Loc. Waldron, Indiana.

MONOMORELLA Billings. Genotype M. prisca Billings.

Monomorella Billings, Canadian Nat. Geol., n. ser., VI, 1871, p. 220;—American Jour. Sci., 3d ser., III, 1872, p. 358.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 155.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 40, 46;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 238.

Monomorella egani Hall and Clarke. Niagara (Sil.).

Monomorella egani Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 42, 175, pl. 4C, fig. 16.

Loc. Near Grafton, Wisconsin.

Digitized by Google

Monomorella greenei Hall and Clarke. Niagara (Sil.).

Monomorella greenii Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 42, 174, pl. 4D, figs. 5–10.

Loc. Near Grafton, Wisconsin; Risingsun, Ohio.

Monomorella kingi Hall and Clarke. Niagara (Sil.).

Monomorella kingi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 42, 174, pl. 4D, figs. 1, 2.

Loc. Near Cedarburg, Wisconsin; Hawthorne, Illinois.

Monomorella newberryi Hall and Whitfield. Niagara (Sil.).

Monomorella newberryi Hall and Whitfield, Pal. Ohio, II, 1875, p. 131, pl. 7, figs. 1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4C, figs. 1, 2.

Loc. Genoa, Ohio.

Monomorella orbicularis Billings. Guelph (Sil.).

Monomorella orbicularis Billings, Canadian Nat. Geol., n. ser., VI, 1871, p. 221;—American Jour. Sci., 3d ser., III, 1872, p. 359.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 158, pl. 17, fig. 10.

Monomorella cnf. orbicularis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4C, figs. 3–5.

Loc. Hespelar, Ontario; near Grafton, Wisconsin.

Monomorella ortoni Hall and Clarke. Niagara (Sil.).

Monomorella ortoni Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 42, 175, pl. 4C, figs. 14, 15.

Loc. Risingsun, Wood County, Ohio.

Monomorella ovata Whiteaves. Guelph (Sil.).

Monomorella ovata Whiteaves, Pal. Fossils, III, 1884, p. 5, pl. 2, fig. 1; pl. 8, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 42, pl. 4D, figs. 13–15.

Loc. Durham, Ontario.

Monomorella ovata lata Whiteaves. Guelph (Sil.).

Monomorella ovata var. lata Whiteaves, Pal. Fossils, III, 1884, p. 6, pl. 2, fig. 2; pl. 8, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4, figs. 11, 12; pl. 4C, figs. 17, 18.

Loc. Durham, Ontario; Hawthorne, Illinois.

Monomorella prisca Billings. Guelph (Sil.).

Monomorella prisca Billings, Canadian Nat. Geol, n. ser., VI, 1871, p. 221;—American Jour. Sci., 3d ser., III, 1872, p. 359.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 156, pl. 17, figs. 5–8.—Nicholson, Pal. Prov. Ontario, 1875, p. 68, fig. 38.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4C, figs. 6–13.

Loc. Hespelar and Elora, Ontario; Risingsun, Wood County, Ohio; Hawthorne, Port Byron, and Cicero, Illinois.

NEWBERRYA Hall. Genotype Rensselæria? johanni Hall.

Rensselandia Hall, Pal. New York, IV, 1867, p. 385.

Newberria Hall, Cont. Canadian Pal., I, 1891, p. 236;—Tenth Ann. Rep. N. Y. State Geol., 1891, p. 91 (extract, p. 4).—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 261;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 851.

Obs. It is unfortunate that Rensselæria johanni is the type for two generic names. Adhering strictly to the rules of nomenclature Rensselandia will take precedence over Newberrya. The first term is, however, improperly constructed and is without meaning.

Digitized by Google

Newberrya claypolei Hall. Hamilton (Dev.).

Rensselæria marylandica? Claypole, Proc. American Phil. Soc., 1883, p. 235.

Newberria claypolii Hall, Tenth Ann. Rep. N. Y. State Geol., 1891, p. 9, extract, pl. 5, figs. 1–9.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 263, pl. 78, figs. 1–9.

Loc. Perry County, Pennsylvania.

Newberria? condoni McChesney=Megalanteris condoni.

Newberrya johannis Hall. Middle Devonian.

Rensselæria? johanni Hall, Pal. New York, IV, 1867, p. 385, pl. 58A, figs. 9–20.

Rensselandia johanni Hall, Ibidem, 1867, at end of description.

Newberria johanni Hall, Cont. Canadian Pal., I, 1891, p. 237.

Newberria johannis Hall, Tenth Ann. Rep. N. Y. State Geol., 1891, p. 8, extract, pl. 6, figs. 1–11.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 262, pl. 78, figs. 10–16.

Loc. Waterloo, Iowa.

Newberrya lævis (Meek). Middle Devonian.

Rensselæria lævis Meek, Trans. Chicago Acad. Sci., I, 1868, p. 108, pl. 13, fig. 8; pl. 14, fig. 4.

Newberria lævis Hall, Cont. Canadian Pal., I, 1891, p. 237, pl. 30, figs. 3, 4.

Newberria lævis Hall, Tenth Ann. Rep. N. Y. State Geol., 1891, p. 7, extract, pl. 6, figs. 12–15.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 264, pl. 78, figs. 17–20.

Loc. Mackenzie, Onion, and Lockhart rivers, Canada.

Newberrya missouriensis Swallow. Hamilton (Dev.).

Newberria missouriensis (Swallow MS.) Hall, Tenth Ann. Rep. N. Y. State Geol., 1891, p. 9, extract, pl. 5, figs. 10–12.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 263, pl. 78, figs. 21–23.

Loc. Moniteau County, Missouri.

NOTOTHYRIS Waagen. Genotype Terebratula subvesicularis David.

Notothyris Waagen, Palæontologica Indica, Ser. XIII, I, 1882, p. 375.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 274;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 857.

Notothyris (?) smithii Derby. Middle Devonian.

Notothyris (?) smithii Derby, Archivos do Museu Nacional do Rio De Janeiro, IX, 1890, p. 81.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 267, 275.

Loc. Head of the Paraguay in Matto-Grosso, Brazil.

NUCLEOSPIRA Hall. Genotype Spirifer ventricosa Hall.

Nucleospira Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 24;—Pal. New York, III, 1859, p. 219;—Ibidem, IV, 1867, p. 278.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 103.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 142;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 806.

Nucleospira barrisi White. Kinderhook (L. Carb.).

Nucleospira barrisi White, Jour. Boston Soc. Nat. Hist., VIII, 1860, p. 227.

Loc. Burlington, Iowa.

Nucleospira concentrica Hall. Lower Helderberg (Dev.).

Nucleospira concentrica Hall, Pal. New York, III, 1859, p. 223, pl. 28B, figs. 15–19.—Hall and Clarke, Ibidem, VIII, Pt. II, 1895, pl. 48, fig. 7.

Loc. Decatur County, Tennessee.

Digitized by Google

Nucleospira concinna Hall. Corniferous-Hamilton (Dev.).

Atrypa concinna Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 200, fig. 3.

Nucleospira concinna Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, pp. 25, 26;—Pal. New York, IV, 1867, p. 279, pl. 45, figs. 33–57.—Davidson, Suppl. British Silurian Brach., Palæontographical Society, 1882, p. 121.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 147.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 103, pl. 32, figs. 1–4.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 145, fig. 131; pl. 48, figs. 12–17, 19–34; pl. 84, fig. 38.

Loc. Moscow, Darien, etc., New York; Monroe County, Pennsylvania; Thedford, Ontario; Hardy County, Virginia; Columbus, Ohio; Falls of Ohio; Lone Mountain, Nevada.

Nucleospira elegans Hall. ?Niagara and L. Helderberg (Sil. and Dev.).

Nucleospira elegans Hall, Pal. New York, III, 1859, p. 222, pl. 28B, figs. 10–15.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 104.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 48, figs. 8–11.

Loc. Cherry Valley, New York; Cumberland, Maryland. In the Niagara near Louisville, Kentucky (Nettelroth).

Nucleospira indianensis Miller=Parazyga hirsuta.

Nucleospira pisiformis Hall. Niagara (Sil.).

Orthis pisum Hall (non Sowerby), Pal. New York, II, 1852, p. 250, pl. 2, fig. 1.

Nucleospira pisiformis Hall, Pal. New York, III, 1859, pl. 28B;—Trans. Albany Institute, IV, 1863, p. 226;—Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 160, pl. 25, figs. 22–28;—Eleventh Rep. State Geol. Indiana, 1882, p. 301, pl. 25, figs. 22–28.—Kayser, Richthofens China, IV, 1883, p. 47, pl. 4, figs. 9–11.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 104, pl. 33, figs. 7–9.—Keyes, Geol. Survey Missouri, V, 1895, p. 94, pl. 41, fig. 5.

Loc. Wolcott, New York; Waldron, Indiana; Louisville, Kentucky; Pike County, Missouri; Tshau-Tien, China.

Nucleospira rotundata Whitfield. Waterlime (Sil.).

Nucleospira rotundata Whitfield, Ann. New York Acad. Sci., II, 1882, p. 194;—Ibidem, V, 1891, p. 511, pl. 5, figs. 11–14;—Geol. Ohio, VII, 1895, p. 413, pl. 1, figs. 11–14.

Loc. Greenfield, Ohio.

Nucleospira ventricosa Hall. Lower Helderberg (Dev.).

Spirifer ventricosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 57.

Nucleospira ventricosa Hall, Pal. New York, III, 1859, p. 220, pl. 14, fig. 1; pl. 28B, figs. 2–9.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 145, figs. 128–130; pl. 48, figs. 2–6, 18; pl. 84, figs. 39, 40.

Loc. Schoharie, Cherry Valley, etc., New York; Cumberland, Maryland.

OBOLELLA Billings. Genotype O. chromatica Billings.

Obolella Billings, Geol. Vermont, II, 1861, p. 946;—Pal. Fossils, I, 1861, p. 7.—Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 131.—Meek and Hayden, Smithsonian Cont. to Knowledge, XIV, 172, 1864, p. 3.—Hall, Trans. Albany Institute, V, 1867, p. 108.—Dall, American Jour. Conchology, VI, 1870, pp. 162, 164.—Billings, Canadian Nat. Geol., n. ser., VI, 1871, p. 217, figs. 5, 6;—American Jour. Sci., 3d ser., III, 1872, p. 355, figs. 5–7;—Ibidem, 3d ser., XI, 1876, p. 176.—Ford, Ibidem, 3d ser., XXI, 1881, p. 131.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 109.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 66, 164;—Eleventh Ann. Rep. N. Y. State Geologist, 1894,

Digitized by Google

OBOLELLA Billings—Continued.

p. 240.—Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 39.—Mickwitz, Mém. l'Acad. Imp. Sci. St. Pétersbourg, VIII, 1896, p. 116.

Dicellomus Hall, Twenty-third Rep. N. Y. State Cab. Nat Hist., 1873, p. 246.

Obolella ambigua Walcott=Elkania ambigua.

Obolella atlantica Walcott. Lower Cambrian.

Obolella atlantica Walcott, Proc. U. S. Nat. Mus., XII, 1889, p. 36;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 611, pl. 71, fig. 1.

Loc. Conception Bay, Newfoundland; Attleboro, Massachusetts.

Obolella cælata Billings=Lingulella cælata.

Obolella chromatica Billings. Lower Cambrian.

Obolella chromatica Billings, Geol. Vermont, II, 1861, p. 947, fig. 346;—Pal. Fossils, I, 1861, p. 7, fig. 7;—Geol. Canada, 1863, p. 284, fig. 288.—Hall, Trans. Albany Institute, V, 1867, p. 110.—Billings, American. Jour. Sci., 3d ser., XI, 1876, p. 176, figs. 1–4.—Ford, Ibidem, 3d ser., XXI, 1881, p. 133, figs. 3, 4, 5.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 112, pl. 11, fig. 1;—Tenth Ann. Rep. U. S. Geol. Survey, p. 611, pl. 71, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 70.

Loc. Anse au Loup, Canada.

Obolella cingulata Billings=Kutorgina cingulata.

Obolella circe Billings. Lower Cambrian.

Obolella circe Billings, Canadian Nat. Geol., n. ser., IV, 1871, p. 218;—American Jour. Sci., III, 1872, p. 357.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 118, pl. 10, fig. 3;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 611, pl. 71, fig. 3.

Loc. Trois Pistoles, Canada.

Obolella crassa (Hall). Lower Cambrian.

Orbicula? crassa Hall, Pal. New York, I, 1847, p. 290, pl. 79, fig. 8.

Avicula? desquamata Hall, Ibidem, 1847, p. 292, pl. 80, fig. 2.

Obolella crassa Billings, Canadian Nat. Geol., n. ser., VI, 1871, p. 218.—Ford, Amer. Jour. Sci., 3d ser., XV, 1878, p. 128;—Ibidem, 3d ser., XXI, 1881, p. 131, figs. 1, 2.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 114, pl. 10, fig. 1.—Shaler and Foerste, Bull. Mus. Comp. Zool., XVI, 1888, p. 27, pl. 1, fig. 1.—Walcott, Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 612, pl. 71, fig. 4.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 70, pl. 2, figs. 31–36.

Obolella desquamata Billings, Canadian Nat. Geol., n. ser., VI, 1871, p. 217, fig. 6;—American Jour. Sci., 3d ser., III, 1872, p. 355, fig. 6.

Obolella (Orbicula?) crassa Ford, American Jour. Sci., 3d ser., II, 1871, p. 33.

Dicellomus crassa Hall, Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, p. 246, pl. 13, figs. 6–9.

Obolella chromatica (lap. crassa) Walcott, American Jour. Sci., 3d ser., XXIX, 1885, p. 116, figs. 1, 2;—Ibidem, XXX, 1890, p. 21.

Loc. Troy and Schodack Landing, New York; North Attleboro, Massachusetts; St. Simon and Bic Harbor, below Quebec, Canada.

Obolella desiderata Billings=Elkania desiderata.

Obolella desquamata Billings=Obolella crassa.

Obolella (?) discoidea Hall and Whitfield. Up. Camb. and Pogonip (Ord.).

Obolella discoidea Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 203, pl. 1, figs. 1, 2.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 14.

Obolella? discoidea Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 111.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 69.

Loc. Eureka district, Nevada.

Digitized by Google

Obolella gemma Billings. Lower Cambrian.

Obolella gemma Billings, Canadian Nat. Geol., n. ser., VI, 1871, p. 217, fig. 5;—American Jour. Sci., 3d ser., III, 1872, p. 357, fig. 5.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 116, pl. 10, fig. 2;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 612, pl. 71, fig. 5; pl. 72, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 71, fig. 30; pl. 2, figs. 42–44.

Loc. Bic and St. Simon harbors, below Quebec, Canada; Troy, New York.

Obolella (?) gemmula Matthew. Upper Cambrian.

Obolella (?) gemmula Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 41, pl. 12, figs. 8a–8c.

Loc. Near St. John, New Brunswick.

Obolella (?) ida Billings. Upper Cambrian and Calciferous (Ord.).

Obolella ida Billings, Pal. Fossils, I, 1862, p. 71, fig. 63, on p. 68.

Obolella ? ida Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 111.

Loc. Point Levis, Canada.

Obolella misera Billings=Linnarssonia misera.

Obolella minuta (Hall and Whitfield). Upper Cambrian.

Lingulepis ? minuta Hall and Whitfield, Rep. Geol. Expl. 40th Parl., IV, 1877, p. 206, pl. 1, figs. 3, 4.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 13.

Loc. Eureka district, Nevada.

Obolella nana Meek and Hayden. Middle Cambrian.

Obolella nana Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 435.—Billings, Pal. Fossils, I, 1862, p. 67.—Hayden, American Jour. Sci., 2d ser., XXXIII, 1863, p. 73.—Meek and Hayden, Smithsonian Cont. to Knowledge, XIV, 172, 1864, p. 4, pl. 1, fig. 3.—Whitfield, Powell's Geol. Geogr. Survey Rocky Mountain Region, 1880, p. 340, pl. 2, figs. 14–17.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 69.

Loc. Black Hills, South Dakota.

Obolella nitida Ford. Lower Cambrian.

Obolella nitida Ford, American Jour. Sci., 3d ser., V, 1873, p. 213.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 118, pl. 11, fig. 2;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 612, pl. 72, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 69, 70.—?Matthew, Trans. N. Y. Acad. Sci., XIV, 1895, p. 125, pl. 2, fig. 8.

Loc. Troy, and Washington County, New York; Hanford Brook, New Brunswick.

Obolella pectenoides (Whitfield). Upper Cambrian.

Obolus pectenoides Whitfield, Ludlow's Rep. Reconn. Black Hills, Dakota, 1875, p. 103, figs. 1–3.

Obolus? pectenoides Whitfield, Powell's Geol. Geogr. Survey Rocky Mountain Region, 1880, p. 338, pl. 2, figs. 18, 19.

Loc. Black Hills, South Dakota.

Obolella polita Hall. Middle Cambrian.

Obolus appolinus Owen (non Eichwald), Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 1B, figs. 9, 11, 15, 20.

Lingula? polita Hall, Ann. Rep. Geol. Survey Wisconsin, 1861, p. 24;—Geol. Rep. Wisconsin, I, 1862, pp. 21, 435.

Obolella ? polita Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 133, pl. 6, figs. 17–21;—Trans. Albany Institute, V, 1867, p. 112.

Lingulepis prima Meek and Hayden, Smithsonian Cont. to Knowl., XIV, 172, 1864, p. 3, pl. 1, fig. 2.

Dicellomus polita Hall, Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, p. 246.

Digitized by Google

Obolella polita Hall—Continued.

Obolella polita Whitfield, Powell's Geol. Geogr. Survey Rocky Mountain Region, 1880, p. 339, pl. 2, figs. 12, 13.—Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 111.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 2, figs. 37–41.

Loc. Trempealeau, Wisconsin; Black Hills, South Dakota.

Obolella pretiosa Billings=Linnarssonia pretiosa.

Obolella prima Whitfield=Lingulepis prima.

Obolella transversa Hartt=Linnarssonia transversa.

Obolellina Billings=Dinobolus.

Obolellina canadensis Billings=Dinobolus canadaensis.

Obolellina galtensis Billings=Rhinobolus galtensis.

Obolellina magnifica Billings=Dinobolus magnificus.

OBOLUS Eichwald. Genotype Obolus appolinus Eichwald.

Obolus Eichwald, Zoologia Specialis, I, 1829, p. 274.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 80, figs. 33, 34; pp. 164, 337.—Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 43.—Mickwitz, Mém. l'Acad. Imp. Sci. St. Pétersbourg, VIII, 1896, pp. 25, 126.

Euobolus Mickwitz, Mém. l'Acad. Imp. Sci. St. Pétersbourg, VIII, 1896, pp. 25, 129, 133.

Obs. Both Euobolus and Obolus are based upon the same species.

Obolus appolinus Owen (non Eichwald)=Obolella polita.

Obolus canadensis Billings, 1858=Dinobolus magnificus.

Obolus canadensis Billings=Dinobolus canadaensis.

Obolus conradi Hall=Dinobolus conradi.

Obolus galtensis Billings=Rhinobolus galtensis.

Obolus labradoricus Billings=Iphidea labradorica.

Obolus (?) major Matthew. Lower Cambrian.

Obolus? major Matthew, Trans. Royal Soc. Canada, IV, 1890, p. 155, pl. 8, fig. 3.

Mickwitzia (?) major Mickwitz, Mém. l'Acad. Imp. Sci. St. Pétersbourg, VIII, 1896, p. 23.

Loc. Near St. John, New Brunswick.

Obolus (?) murrayi Billings. Cambrian.

Obolus? murrayi Billings, Pal. Fossils, I, 1865, p. 362.

Loc. Hare Bay, Newfoundland.

Obolus ? pectenoides Whitfield=Obolella pectinoides.

Obolus pulcher Matthew=Botsfordia pulchra.

Obolus pristinus Matthew. ?Middle Cambrian.

Obolus pristinus Matthew, Trans. N. Y. Acad. Sci., XIV, 1895, p. 121, pl. 4, fig. 1.

Loc. Hanford Brook, New Brunswick.

Obolus (?) refulgens Matthew. Middle Cambrian.

Obolus refulgens Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 44, pl. 12, figs. 6a–6d.

Obolus (?) refulgens Mickwitz, Mém. l'Acad. Imp. Sci. St. Pétersbourg, VIII, 1896, p. 23.

Loc. Near St. John, New Brunswick.

Œhlertella Hall and Clarke=Lingulodiscina.

Orbicula Cuvier=Crania.

Orbicula Sowerby, 1830=Discina.

Orbicula cælata Hall=Lingulella cælata.

Digitized by Google

Orbicula corrugata Hall=Lichenalia, a bryozoan.

Orbicula crassa Hall=Obolella crassa.

Orbicula deformata Hall=Crania deformata.

?Orbicula excentrica Emmons. Cambrian.

Orbicula excentrica Emmons, American Geology, Pt. II, 1855, p. 112, pl. 1, fig. 4.
Crania excentrica Miller, N. American Geol. Pal., 1889, p. 341.
Loc. Augusta County, Virginia.
Obs. Probably a gastropod.

Orbicula filosa Hall=Schizocrania filosa.

Orbicula grandis Vanuxem=Rœmerella grandis.

Orbicula lamellosa Hall (non Broderip)=Orbiculoidea lamellosa.

Orbicula lodensis Vanuxem=Orbiculoidea lodiensis.

Orbicula lugubris Conrad=Discinisca lugubris.

Orbicula minuta Hall=Orbiculoidea minuta.

Orbicula multilineata Conrad=Discinisca multilineata.

Orbicula parmulata Hall=Orbiculoidea parmulata.

Orbicula prima Owen=Lingulepis pinniformis.

Orbicula squamiformis Hall=Pholidops squamiformis.

Orbicula subtruncata Hall=Pholidops subtruncata.

Orbicula tenuilamellata Hall=Schizotreta tenuilamellata.

Orbicula terminalis Emmons=Trematis terminalis.

Orbicula truncata Emmons=Orbiculoidea lamellosa.

ORBICULOIDEA d'Orbigny. Genotype Orbicula morrisi Davidson.

Orbiculoidea d'Orbigny, Prodrome de Paléontologie stratigraphique, I, 1850, p. 44.—Dall, Bull. Mus. Comp. Zool., III, 1871, p. 37;—American Jour. Conch., VII, 1871, p. 74.—Herrick, Bull. Denison Univ., IV, 1888, p. 12.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 125, fig. 64; p. 128, fig. 160 and pp. 160, 168.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 363.—Hall and Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 256.
Discina Hall (non Lamarck), Pal. New York, III, 1859, p. 159;—Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 130;—Pal. New York, IV, 1867, p. 15.

Orbiculoidea alleghania (Hall). Chemung (Dev.).

Discina alleghania Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 77, figs. 1, 2;—Pal. New York, IV, 1867, p. 25, fig. 1, pl. 1, fig. 17.
Loc. Hobbieville, Alleghany County, New York.

Orbiculoidea ampla Hall. Oriskany (Dev.).

Discina grandis Hall (non Vanuxem, 1842), Pal. New York, III, 1859, p. 406, pl. 92, fig. 1.
Discina ampla Hall, Ibidem, corrigenda in volume with plates, 1859.
Orbiculoidea ampla Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 127.
Loc. Albany County, New York; Cayuga, Ontario.

Orbiculoidea baini (Morris and Sharpe.) Middle Devonian.

Orbicula baini Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 277, pl. 10, fig. 5.—Sharpe and Salter, Trans. Geol. Soc. London, 2d ser., VII, 1856, p. 210, pl. 26, figs. 20–23.
Discina baini von Ammon, Zeits. Gessels. für Erdk., Berlin, XXVIII, 1893, p. 359, fig. 4.
Loc. Falkland Islands; Taquarassu, Matto-Grosso, Brazil; South Africa.

Digitized by Google

Orbiculoidea (?) capax (White). Kinderhook (L. Carb.).

Discina capax White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 30.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 112;—Proc. American Phil. Soc., XII, 1870, p. 249.

Loc. Burlington, Iowa; Girard and Rockville, Ohio (A. Winchell).

Obs. This species should be compared with Lingulodiscina newberryi Hall.

Orbiculoidea capuliformis (McChesney). Upper Carboniferous.

Discina capuliforma McChesney, New Pal. Fossils, 1860, p. 72;—Trans. Chicago Acad. Sci., I, 1868, p. 73, pl. 2, fig. 20.

Loc. Springfield, Illinois.

Obs. Compare with O. convexa Shumard.

Orbiculoidea conica Dwight=Schizotreta conica.

Orbiculoidea conradi (Hall). Lower Helderberg (Dev.).

Discina conradi Hall, Pal. New York, III, 1859, p. 161, pl. 9, figs. 16, 17; pl. 10A. fig. 2.

Loc. Near Hudson, New York.

Orbiculoidea convexa (Shumard). Upper Carboniferous.

Discina convexa Shumard, Trans. St. Loius Acad. Sci., I, 1858, p. 221.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 121, pl. 25, fig. 9.—Herrick, Bull. Denison Univ., II, 1887, pl. 3, fig. 19.—Keyes, Geol. Survey Missouri, V, 1895, p. 40, pl. 35, fig. 7.

Loc. Valley of Verdigris River, Kansas; Kansas City, Missouri; Vermilion County, Indiana; Newark, Ohio.

Obs. See Orbiculoidea capuliformis McChesney.

Orbiculoidea discus Hall. Lower Helderberg (Dev.).

Discina discus Hall, Pal. New York, III, 1859, p. 159, pl. 9, figs. 13–15.

Schizocrania (?) discus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 132.

Orbiculoidea discus Hall and Clarke, Ibidem, 1892, pl. 4E, fig. 13.

Loc. Near Hudson and Albany counties, New York.

Orbiculoidea doria (Hall). Hamilton (Dev.).

Discina doria Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 26;—Pal. New York, IV, 1867, p. 19, pl. 2, figs. 19–22, 31 (?30).—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 32.

Loc. Madison County, New York; Thedford, Ontario; Clark County, Indiana.

Orbiculoidea elmira (Hall). Chemung (Dev.).

Discina elmira Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 29;—Pal. New York, IV, 1867, p. 24, pl. 2, figs. 38, 39.

Loc. Elmira, New York; Wellsboro, Pennsylvania.

Orbiculoidea gallaheri (A. Winchell). Marshall (L. Carb.).

Discina gallaheri A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 112;—Proc. American Philosophical Soc., XII, 1870, p. 249.

Loc. Hillsdale, Michigan; Granville, Ohio; Shafers, Pennsylvania.

Orbiculoidea herzeri Hall and Clarke. Waverly (L. Carb.).

Orbiculoidea herzeri Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 126, 127, 178.

Orbiculoidea pulchra Hall and Clarke, Ibidem, 1892, pl. 4E, fig. 19; pl. 4F, figs. 9–13, 30, (?14–16).

Loc. Berea and Baconsburg, Ohio; Meadville, Pennsylvania.

Orbiculoidea humilis (Hall). Marcellus and Hamilton (Dev.).

Discina humilis Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 25;—Pal. New York, IV, 1867, p. 16, pl. 2, fig. 18.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 560;—Geol. Ohio, VII, 1895, p. 452, pl. 8, figs. 1, 2.

Loc. Bridgewater, Canandaigua Lake, etc., New York; Leroy, Ohio.

Digitized by Google

Orbiculoidea illinoisensis (Miller and Gurley). Upper Carboniferous.

Discina illinoiensis Miller and Gurley, Bull. Illinois State Mus. Nat. Hist., 3, 1893, p. 70, pl. 7, figs. 2–5.

Loc. Knox and Peoria counties, Illinois.

Obs. Closely related to O. convexa.

Orbiculoidea jervisensis (Barrett). Oriskany (Dev.).

Discina jervensis Barrett, Annals N. Y. Acad. Sci., I, 1878, p. 121.

Loc. Port Jervis, New York.

Orbiculoidea keokuk (Gurley). Keokuk (L. Carb.).

Discina keokuk Gurley, New Carb. Fossils, 1884, p. 6.

Loc. Crawfordsville, Indiana.

Orbiculoidea lamellosa Hall. Trenton and Lorraine (Ord.).

Orbicula lamellosa Hall (non Broderip, 1833), Pal. New York, I, 1847, p. 99, pl. 30, fig. 10.

Orbicula truncata Emmons, American Geology, Pt. II, 1855, p. 200, fig. 62.

Discina truncata Emmons, Manual of Geol., 1860, p. 99.

Orbiculoidea lamellosa? Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 364, pl. 29, fig. 25.

Orbiculoidea lamellosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4E, fig. 12.

Discina circe Billings, Pal. Fossils, I, 1862, p. 51, fig. 55;—Geol. Canada, 1863, p. 159, fig. 125.

Loc. Middleville and Lowville, New York; Bellville and Ottawa, Canada; Spring Valley, Minnesota.

Obs. Orbicula lamellosa Broderip, is the type species of Discinisca, and Hall's name will therefore stand.

Orbiculoidea lodiensis (Vanuxem). Genesee (Dev.).

Orbicula lodensis Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 168, fig. 1.—Hall, Ibidem, Rep. Fourth Dist., 1843, p. 223, fig. 1.

Discina lodensis Hall, Pal. New York, IV, 1867, p. 22, pl. 1, fig. 14; pl. 2, fig. 35.—Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 257;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 17.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 112, pl. 2, fig. 5.—Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 24.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 547, pl. 11, fig. 7;—Geol. Ohio, VII, 1895, p. 442, pl. 7, fig. 7.

Discina sp. a A. Ulrich, N. Jahrb. für Mineral., Beilageband, VIII, 1892, p. 81, pl. 5, fig. 10.

Orbiculoidea lodensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4F, fig. 21.

Loc. Lodi, etc., New York; White Pine district, Nevada; Erere, Province of Para, Brazil; Chahuarani, Bolivia. In the Marcellus shale of Delaware County, Ohio (Whitfield).

Orbiculoidea lodiensis media Hall. Marcellus-Chemung (Dev.).

Discina media Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 27;—Pal. New York, IV, 1867, p. 20, pl. 2, figs. 25–29.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 113.

Orbiculoidea media Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4E, figs. 15–17.

Loc. Seneca and Canandaigua lakes, New York; Chemung group, Troupsburg, New York.

Orbiculoidea magnifica (Herrick). Waverly (L. Carb.).

Discina magnifica Herrick, Bull. Geol. Soc. America, II, 1891, p. 46, pl. 1, fig. 17.

Loc. Wooster, and Ashland County, Ohio.

Digitized by Google

Orbiculoidea manhattanensis (Meek and Hayden). Upper Carboniferous.

Discina manhattensis Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p. 25.

Loc. Near Manhattan, Kansas.

Orbiculoidea marginalis (Whitfield). Hamilton (Dev.).

Discina marginalis Whitfield, Ann. Rep. Geol. Survey Wisconsin, 1880, p. 70;—Geol. Survey Wisconsin, IV, 1882, p. 325, pl. 25, fig. 11.

Orbiculoidea marginalis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 127, pl. 4F, fig. 17.

Loc. Milwaukee, Wisconsin.

Orbiculoidea minuta (Hall). Marcellus-Hamilton (Dev.).

Orbicula minuta Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 180, fig. 9.

Discina minuta Hall, Pal. New York, IV, 1867, p. 16, pl. 1, fig. 16.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 112, pl. 13, fig. 5.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 547, pl. 11, figs. 5, 6;—Geol. Ohio, VII, 1895, p. 442, pl. 7, figs. 5, 6.

Orbiculoidea minuta Beecher, American Jour. Sci., 3d ser., XLI, 1891, p. 356, pl. 17, figs. 5–7;—American Jour. Sci., 3d ser., XLIV, 1892, p. 150, pl. 1, figs. 4–6.

Loc. Avon, New York; Delaware County, Ohio; near Eureka, Nevada.

Orbiculoidea missouriensis (Shumard). Upper Carboniferous.

Discina missouriensis Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 221.

Discina nitida? Meek and Worthen (non Phillips), Geol. Survey Illinois, V, 1873, p. 572, pl. 25, fig. 1.

Discina nitida White, Thirteenth Rep. State Geologist Indiana, 1884, p. 121, pl. 25, fig. 10.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 226.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 131, pl. 4F, figs. 23–28.—Keyes, Geol. Survey Missouri, V, 1895, p. 39, pl. 35, fig. 6.

Discina meekana Whitfield, Annals N. Y. Acad. Sci., II, 1882, p. 228.—Herrick, Bull. Denison Univ., II, 1887, p. 145, pl. 2, fig. 8.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 598, pl. 15, figs. 1–3;—Geol. Ohio, VII, 1895, p. 483, pl. 11, figs. 1–3.

Loc. Lexington, Missouri; Illinois; Carbon Hill and Flint Ridge, Ohio; Des Moines, Iowa; Vermilion County, Indiana.

Obs. This species is not D. nitida Phillips. It differs from it in form and in the muscular scars.

Orbiculoidea (?) munda (Miller and Gurley). Upper Carboniferous.

Discina munda Miller and Gurley, Bull. Illinois State Mus. Nat. Hist., 3, 1893, p. 71, pl. 7, figs. 6, 7.

Loc. Kansas City, Missouri.

Obs. This species may be a Lingulodiscina, but since the ventral valve is unknown satisfactory generic reference can not be made.

Orbiculoidea neglecta (Hall). Chemung (Dev.).

Discina neglecta Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 29;—Pal. New York, IV, 1867, p. 24, pl. 1, figs. 12, 13.

Loc. Ithaca, New York.

Orbiculoidea newberryi Meek=Lingulodiscina newberryi.

Orbiculoidea nitida (Phillips). Upper Carboniferous.

Orbicula nitida Phillips, Geol. Yorkshire, II, 1836, p. 221, pl. 9, figs. 10–13.

?Discina nitida Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 213, pl. 7, fig. 4.

Loc. England; White Pine district, Nevada.

Digitized by Google

Orbiculoidea numulus Hall and Clarke. Waterlime (Sil.).
Orbiculoidea numulus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 178, pl. 4E, fig. 14.
Loc. Marshall, New York.

Orbiculoidea parmulata (Hall). Medina (Sil.).
Orbicula parmulata Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 48, fig. 4;—Pal. New York, II, 1852, pl. 4, fig. 3.
Loc. Medina and Lockport, New York.

Orbiculoidea patellaris (A. Winchell). Kinderhook (L. Carb.).
Discina patellaris A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 4.
Loc. Burlington, Iowa.

Orbiculoidea pleurites Meek=Lingulodiscina pleurites.

Orbiculoidea pulchra Hall=Orbiculoidea hertzeri.

Orbiculoidea randalli Hall. Hamilton (Dev.).
Discina randalli Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 25;—Pal. New York, IV, 1867, p. 18, pl. 2, fig. 34.
Orbiculoidea randalli Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4E, fig. 18.
Loc. Schoharie, New York.

Orbiculoidea saffordi (A. Winchell). Lower Carboniferous.
Discina saffordi A. Winchell, Geol. Tennessee, 1869, p. 443;—Proc. American Philosophical Soc., XII, 1870, p. 248.
Loc. "Just above Black Slate," Hickman County, Tennessee.

Orbiculoidea sampsoni (Miller). Chouteau (L. Carb.).
Discina sampsoni Miller, Seventeenth Rep. State Geol. Indiana, 1891, p. 80, pl. 13, figs. 10–12.
Loc. Sedalia, Missouri.

Orbiculoidea seneca (Hall). Hamilton (Dev.).
Discina seneca Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 26;—Pal. New York, IV, 1867, p. 20, pl. 2, figs. 23, 24.
Loc. East shore of Seneca Lake, New York.

Orbiculoidea subplana (Hall). Arisaig (Sil.).
Discina tenuilamellata var. subplana Hall, Canadian Nat. Geol., V, 1860, p. 144.—Dawson, Acadian Geol., 3d ed., 1878, p. 595.
Loc. Arisaig, Nova Scotia.

Orbiculoidea subtrigonalis (McChesney). Upper Carboniferous.
Discina subtrigonalis McChesney, New Pal. Fossils, 1865, p. 97.
Discina trigonalis McChesney, Ibidem, 1865, pl. 2, fig. 19;—Trans. Chicago Acad. Sci., I, 1868, p. 24, pl. 2, fig. 19.
Loc. Lasalle, Illinois.

Orbiculoidea tenuilineata (Meek and Hayden). Upper Carboniferous.
Discina tenuilineata Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p. 25.
Loc. Cottonwood Creek, Kansas.

Orbiculoidea tenuistriata (Ulrich). Utica (Ord.).
Discina tenuistriata Ulrich, Jour. Cincinnati Soc. Nat. Hist., I, 1878, p. 96, pl. 4, fig. 10.
Loc. Covington, Kentucky.

Digitized by Google

Orbiculoidea tullia (Hall). Tully (Dev.).

Discina tullia Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 28;—Pal. New York, IV, 1867, p. 22, pl. 2, figs. 16, 17.

Loc. Seneca Lake, New York.

Orbiculoidea utahensis (Meek). Upper Carboniferous.

Discina sp. undet., Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 99, pl. 10, fig. 3.

Discina utahensis Meek, Ibidem, 1877, p. 99 (also see footnote, p. 9).

Loc. Weber Canyon, Wasatch Range, Utah.

Orbiculoidea vanuxemi (Hall). Arisaig and Waterlime (Sil.).

Discina vanuxemi Hall, Pal. New York, III, 1859, p. 162, pl. 8, fig. 1.

Loc. Manlius-square, New York; Arisaig, Nova Scotia (Ami).

Orbiculoidea varsaviensis (Worthen). Keokuk (L. Carb.).

Discina varsoviensis Worthen, Bull. Illinois State Mus. Nat. Hist., 2, 1884, p. 23;—Geol. Survey Illinois, VIII, 1890, p. 102, pl. 11, fig. 7.

Loc. Warsaw, Illinois.

ORISKANIA Hall and Clarke. Genotype O. navicella H. and C.

Oriskania Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 270;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 854.

Oriskania navicella Hall and Clarke. Oriskany (Dev.).

Oriskania navicella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 269, figs. 181–183, pl. 79, figs. 25–27.

Loc. Near Hudson, New York.

ORTHIDIUM Hall and Clarke. Genotype Orthis gemmicula Billings.

Orthidium Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 244;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 276.

Orthidium gemmicula (Billings). Calciferous (Ord.).

Orthis gemmicula Billings, Pal. Fossils, I, 1862, p. 75, fig. 68.

Orthidium gemmicula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 217, 244, pl. 7A, figs. 22–25.

Loc. Point Levis, Canada.

Orthis of authors.

Orthis Hall, Pal. New York, IV, 1867, p. 33.—Shaler, Fossil Brachiopoda of the Ohio Valley, 1887, p. 18.—Herrick, Bull. Denison University, IV, 1888, p. 14.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 34.—Hall, Bull. Geol. Soc. America, I, 1889, p. 19.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 185, 186;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 264.

ORTHIS Dalman (emend Hall and Clarke). Genotype Orthis calligramma Dalman.

Orthis Dalman, Kongl. Svenska Vet.-Akad. Handl., för 1827, 1828, pp. 93, 96.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 192.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 417.—Hall and Clarke, Eleventh Ann. Rep. State Geologist, 1894, p. 265.

Orthis æquivalvis Hall, 1847=Plectorthis æquivalvis.

Orthis æquivalvis Hall, 1857 (non 1847)=Orthis eryna.

Orthis æquivalvis Shaler (non Hall)=Rhipidomella uberis.

Orthis (?) acuminata Billings. Chazy (Ord.).

Orthis ? acuminata Billings, Canadian Nat. Geol., IV, 1859, p. 440, fig. 19.

Orthis acuminata Billings, Geol. Canada, 1863, p. 130, fig. 59.

Loc. Caughnawaga, Canada.

Digitized by Google

Orthis acutilirata Meek=Platystrophia acutilirata.
Orthis acutiloba Ringueberg=Bilobites acutilobus.
Orthis alata Shaler=Orthis davidsoni.
Orthis alsus Hall=Rhipidomella alsa.

Orthis (?) alternans Castelnau. Formation.?

Orthis alternans Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 38, pl. 14, fig. 2.

Loc. "From an erratic block, Lake of the Woods." Undeterminable.

Orthis amœna N. H. Winchell=Dalmanella amœna.
Orthis anticostiensis Shaler=Dinorthis porcata.

Orthis (?) apicalis Billings. ?Upper Cambrian.

Orthis ? apicalis Billings, Pal. Fossils, I, 1865, p. 301, fig. 291.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217.

Loc. Point Levis and west end of Island of Orleans, Canada.

Orthis arachnoides Roemer and Hall (non Phillips)=Derbya crassa.
Orthis armanda Billings=Syntrophia armanda.
Orthis assimilis Hall=Rhipidomella assimilis.
Orthis aurelia Billings=Plectorthis aurelia.
Orthis aymara Salter=Anoplotheca flabellites.
Orthis barabuensis Winchell=Syntrophia barabuensis.
Orthis battis Billings=Hebertella battis.
Orthis bellarugosa Conrad=Hebertella bellirugosa.
Orthis bellarugosa Hall, 1883=Hebertella insculpta.
Orthis bellula Meek=Dalmanella bellula.

Orthis benedicti Miller. Niagara (Sil.).

Orthis benedicti Miller, Seventeenth Rep. State Geol. Indiana, 1891, p. 78, pl. 13, figs. 7–9.

Loc. Hartsville, Indiana.

Orthis bicostatus Vanuxem=Reticularia bicostata.
Orthis biforata of authors=Platystrophia biforata.
Orthis biforata acutilirata White=Platystrophia acutilirata.
Orthis billingsi Hartt=Billingsella billingsi.
Orthis biloba Hall=Bilobites bilobus.
Orthis bisulcata Emmons=Cyclospira bisulcata.
Orthis borealis Billings=Hebertella borealis.

Orthis(?) buchi d'Orbigny. Upper Carboniferous.

Orthis buchi d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 49.
Productus andii d'Orbigny, Ibidem, p. 54, pl. 5, figs. 1–3.—de Koninck, Recher. Animaux Foss., Pt. I, 1847, p. 238.

Loc. Yarbichambi, Bolivia.

Orthis calligramma Foerste (non Dalman)=Orthis flabellites.
Orthis calligramma davidsoni Nicholson and Hinde=Orthis davidsoni.

Orthis calligramma Kayser. Lower Ordovician.

Orthis calligramma Kayser (non Davidson), Palæontographica, Suppl., III, 1876, pp. 18, 26, pl. 3, figs. 9–18.

Loc. Cordillere San Juan, Argentine Republic.

Obs. These shells appear to be more closely related to O. plicatella than to O. calligramma.

Digitized by Google

Orthis canalis Hall=Dalmanella elegantula.
Orthis carbonaria Swallow=Rhipidomella pecosi.
Orthis carinata Hall=Schizophoria carinata.
Orthis carleyi Hall=Dinorthis retrorsa.

Orthis carausii Salter. Calciferous (Ord.).

Orthis carausii (Salter, MS.) Davidson, Geol. Mag. London, V, 1868, p. 315, pl. 16, fig. 23.
Orthis carausii? Matthew, Trans. Royal Soc. Canada, X, 1893, p. 102, pl. 7, fig. 7.
Loc. England; near St. John, New Brunswick.

Orthis (?) centrilineata Hall. Lorraine (Ord.).

Orthis centrilineata Hall, Pal. New York, I, 1847, p. 289, pl. 79, fig. 5*.
Loc. Lorraine and Turin, New York.

Orthis centrosa Miller=Platystrophia crassa.
Orthis charlottæ Winchell=Dinorthis pectinella.
Orthis cincinnatiensis Miller=Orthis? pumila.
Orthis (?) circularis N. H. Winchell=Dalmanella subæquata circularis.
Orthis circulus Hall=Rhipidomella circulus.
Orthis clarkensis Swallow=Rhipidomella clarkensis.
Orthis cleobis Hall=Rhipidomella cleobis.
Orthis clytie Hall=Heterorthis clytie.
Orthis coloradoensis Meek, 1870=Orthis? desmopleura.
Orthis coloradoensis Shumard=Billingsella coloradoensis.
Orthis concinna Hall=Dalmanella concinna.

Orthis (?) concinna Morris and Sharpe. Lower Devonian.

Orthis concinna Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 275, pl. 10, fig. 2.
Loc. Falkland Islands.
Obs. Probably a species of Orthothetes.

Orthis conradi Castelnau=Hipparionyx proximus.
Orthis conradi N. H. Winchell=Dalmanella subæquata conradi.
Orthis cooperensis Swallow=Rhipidomella dubia.
Orthis cora d'Orbigny=Schizophoria cora.

Orthis corinna Billings. Calciferous (Ord.).

Orthis corinna Billings, Pal. Fossils, I, 1865, p. 302, fig. 292.
Orthis? corinna Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217.
Loc. Stanbridge, Quebec, Canada.

Orthis corpulenta Sardeson=Dalmanella testudinaria meeki.

Orthis costalis Hall. Chazy (Ord.).

Orthis costalis Hall, Pal. New York, I, 1847, p. 20, pl. 4 bis, fig. 4;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 34, figs. 35-38.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 221, 228, pl. 5, figs. 15-17.
Loc. Chazy, New York.

Orthis costata Hall (non Sowerby)=Orthis pumila.
Orthis crassa James=Platystrophia crassa.
Orthis crenistria Geinitz=Derbya crassa.
Orthis crispata Emmons=Dalmanella crispata.
Orthis cumberlandia Hall=Rhipidomella cumberlandia.
Orthis cuneata Owen=Rhipidomella cuneata.

Digitized by Google

Orthis cyclas Hall=Rhipidomella cyclas.
Orthis cyclus James=Dalmanella testudinaria emacerata.
Orthis cypha James=Platystrophia laticosta.
Orthis dalyana Miller=Rhipidomella dalyana.

Orthis davidsoni de Verneuil. Anticosti and Niagara (Sil.).

Orthis davidsoni de Verneuil, Bull. Soc. Géol. de France, 2d ser., V, 1848, p. 341, pl. 4, fig. 9.—Billings, Geol. Canada, 1863, p. 312, fig. 318.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 192, 193, 221, 228, pl. 5, figs. 5–8.
Orthis alata Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 66.
Orthis calligramma var. davidsoni Nicholson and Hinde, Canadian Jour., n. ser., XIV, 1874, p. 144.—Nicholson, Pal. Prov. Ontario, 1875, p. 47, fig. 21g.
Loc. Europe; Anticosti; Dundas, Ontario.

Orthis daytonensis Foerste=Hebertella daytonensis.
Orthis deformis Hall=Orthothetes deformis.

Orthis (?) delicatula Billings. ? Calciferous (Ord.).

Orthis delicatula Billings, Pal. Fossils, I, 1865, p. 217.
Loc. Pistolet Bay and near Portland Creek, Newfoundland.

Orthis dentata Meek (non Pander)=Platystrophia crassa.

Orthis (?) desmopleura Meek. Calciferous (Ord.).

Orthis coloradoensis Meek (non Shumard), Proc. American Phil. Soc., II, 1870, p. 425.
Orthis desmopleura Meek, Hayden's U. S. Geol. Survey Wyoming, 1872, p. 295.
Loc. Colorado City and Manitou, Colorado.

Orthis dichotoma Hall=Plectorthis dichotoma.
Orthis discus Hall=Rhipidomella discus.
Orthis disparilis Conrad=Orthis tricenaria.
Orthis disparilis Owen=Dalmanella testudinaria.

Orthis disparilis Kayser. Ordovician.

Orthis disparilis Kayser (non Conrad), Palæontographica, Suppl., III, 1876, p. 26, pl. 3, figs. 4–8.
Loc. Potrero de los Angulos, etc., Argentine Republic.
Obs. Probably a new species.

Orthis dubia Hall=Rhipidomella dubia.
Orthis eboracensis Miller=Dalmanella lenticularis.
Orthis electra Billings=Dalmanella electra.
Orthis elegantula Dalman=Dalmanella elegantula.
Orthis elegantula parva Foerste=Dalmanella elegantula parva.
Orthis ella Hall=Plectorthis ella.
Orthis emacerata Hall=Dalmanella testudinaria emacerata.
Orthis emacerata Meek (non Hall)=Dalmanella testudinaria meeki.
Orthis emarginata Hall=Rhipidomella oblata emarginata.
Orthis eminens Hall=Rhipidomella eminens.
Orthis erratica Hall=Catazyga erratica.

Orthis (?) eryna Hall. Corniferous (Dev.).

Orthis æquivalvis Hall (non Hall, 1847), Tenth Rep. New York State Cab. Nat. Hist., 1857, p. 109.
Orthis eryna Hall, Sixteenth Rep. Ibidem, 1863, p. 35;—Pal. New York, IV, 1867, corrigenda.
Orthis idas Hall, Pal. New York, IV, 1867, p. 42, pl. 5, fig. 11.
Loc. Williamsville, New York.
Obs. Possibly a species of Hipparionyx.

Digitized by Google

Orthis (?) eudocia Billings. Calciferous (C

Orthis eudocia Billings, Pal. Fossils, I, 1862, p. 83, fig. 76.

Loc. Point Levis, Canada.

Orthis (?) eurekaensis Walcott. Upper Camb

Orthis eurekensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 22, pl. 9

Protorthis? eurekensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,

Loc. Eureka district, Nevada.

Orthis euryone Billings. Calciferous (C

Orthis euryone Billings, Pal. Fossils, I, 1862, p. 78, fig. 71.—Hall and Clark New York, VIII, Pt. I, 1892, pp. 221, 228, pl. 5, fig. 4.

Orthis euryone? Matthew, Trans. Royal Soc. Canada, 1893, p. 101, pl. 7, fig. 5

Loc. Point Levis, Canada; near St. John, New Brunswick.

Orthis evadne Billings=Dalmanella evadne.

Orthis fasciata Hall=Orthostrophia fasciata.

Orthis fausta Foerste=Hebertella fausta.

Orthis fissicosta Meek, and Miller=Plectorthis dichotoma.

Orthis fissicosta Hall=Plectorthis fissicosta.

Orthis (?) fissiplica Roemer. Niagara

Orthis fissiplica Roemer, Die silurische Fauna des west. Tennessee, 1860, pl. 5, fig. 5.

Loc. Perry County, Tennessee.

Orthis flabella Hall=Orthis flabellites.

Orthis flabellites Foerste. Clinton and Niagara

Orthis flabellulum? Hall (non Sowerby), Geol. N. Y.; Rep. Fourth Dist., 1 105, fig. 5.

Orthis flabellulum var. Hall, Pal. New York, II, 1852, pp. 254, 255, pl. 52, fi

Orthis flabellulum Billings, Canadian Nat. Geol., I, 1856, p. 136, pl. 2, fi Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1 38, pl. 34, fig. 30.

Orthis flabella Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 34, figs. pl. 35, figs. 6–8.—Foerste, Bull. Denison Univ., I, 1885, p. 82, pl. 13,

Orthis calligramma Foerste (non Dalman), Proc. Boston Soc. Nat. Hist., 1890, p. 308, pl. 6, figs. 4, 5.

Orthis flabellites Foerste, Ibidem, 1890, p. 311.—Hall and Clarke, Pal. New VIII, Pt. I, 1892, pp. 221, 227, pl. 5, figs. 37–41; pl. 20, fig. 1.

Orthis (Dinorthis) calligramma Foerste, Geol. Ohio, VII, 1895, p. 570, figs. 12a, 12b; pl. 31, figs. 4, 5; pl. 37A, fig. 20.

Loc. Lockport, Rochester, etc., New York; Dayton, Ohio; Osgood, In Louisville, Kentucky; Milwaukee, Wisconsin; Dundas, Ontario.

Orthis flabellites spania Hall and Clarke. Niagara

Orthis flabellites var. spania Hall and Clarke, Pal. New York, VIII, 1895, pl. 84, figs. 10.

Loc. Near Milwaukee, Wisconsin.

Orthis flabellulum Hall (non Sowerby)=Orthis flabellites.

Orthis (?) flava A. Winchell. Kinderhook (L. C

Orthis flava A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 117.

Loc. Burlington, Iowa.

Orthis futilis Sardeson=Dalmanella testudinaria futilis.

Orthis gemmicula Billings=Orthidium gemmicula.

Orthis gibbosa Billings=Dalmanella subæquata gibbosa.

Orthis goodwini Nettelroth=Rhipidomella goodwini.

Digitized by Google

Orthis (?) glypta Hall and Clarke. Niagara (Sil.).

Orthis ? glypta Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 359, pl. 84, figs. 8, 9.

Loc. Near Milwaukee, Wisconsin.

Orthis halli Safford=Orthostrophia strophomenoides.

Orthis hamburgensis Walcott=Dalmanella hamburgensis.

Orthis harttii Rathbun=Rhipidomella hartti.

Orthis (?) highlandensis Walcott. Lower Cambrian.

Orthis(?) highlandensis Walcott, Bull. U. S. Geol. Survey, 30, 1886, p. 119, pl. 8, fig. 3.

Orthis highlandensis Walcott, Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 612, pl. 72, fig. 5.

Loc. Pioche and Highland Range, Nevada.

Orthis hipparionyx Hall=Hipparionyx proximus.

Orthis hippolyte Billings. Calciferous (Ord.).

Orthis hippolyte Billings, Pal. Fossils, I, 1862, p. 81, fig. 73; p. 218.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 217, 221, 228.

Orthis hippolyte? Meek, Sixth Ann. Rep. U. S. Geol. Survey Terr., 1873, p. 464.

Loc. Point Levis and Phillipsburg, Canada; Cow Head, Newfoundland; near Malade City, Utah.

Orthis (?) holstoni Safford. Trenton (Ord.).

Orthis? holstoni (Safford MS.) Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 218, 340, pl. 5A, figs. 35–37.

Loc. Near Nashville, Tennessee.

Orthis humboldti d'Orbigny. Silurian.

Orthis humboldtii d'Orbigny, Voyage dans l'Amériqne Méridionale, Pal., 1842, p. 27.

Spirifer humboldtii d'Orbigny, Ibidem, pl. 2, figs. 16–20.

Loc. Bolivia.

Orthis huroniensis Castlenau=Rafinesquina alternata.

Orthis hybrida Sowerby=Rhipidomella hybrida.

Orthis idas Hall=Orthis eryna.

Orthis idonea Hall=Rhipidomella idonea.

Orthis ignota Sardeson=Dalmanella testudinaria ignota.

Orthis imperator Billings=Hebertella imperator.

Orthis impressa Hall=Schizophoria striatula.

Orthis inequalis Hall=Orthothetes inæqualis.

Orthis inca d'Orbigny=Rhipidomella inca.

Orthis infera Calvin=Dalmanella infera.

Orthis insculpta Hall=Hebertella insculpta.

Orthis insignis Hall=Scenidium insignis.

Orthis interlineata Hall (non Sowerby)=Schizophoria tioga.

Orthis interstriata Hall=Orthothetes interstriatus.

Orthis iowensis Hall=Schizophoria striatula.

Orthis iowensis furnarius Hall=Schizophoria striatula.

Orthis iphigenia Billings=Dinorthis iphigenia.

Orthis jamesi Hall=Plectorthis jamesi.

Orthis jugosa James=Dalmanella testudinaria meeki.

Orthis kankakensis McChesney=Plectorthis kankakiensis.

Digitized by Google

Orthis kaskaskiensis McChesney=Derbya kaskaskiaensis.
Orthis kassubæ Winchell=Dalmanella subæquata pervetus.
Orthis kennicotti McChesney=Dinorthis retrorsa.
Orthis keokuk Hall=Derbya keokuk.
Orthis lasallensis McChesney=Derbya crassa.
Orthis laticosta Meek=Platystrophia laticosta.

Orthis (?) laticostata d'Orbigny. **Dev**

Orthis lacticostata d'Orbigny, Voyage dans l'Amérique Méridionale, Pal
p. 39.
Loc. ? Bolivia.

Orthis laurentina Billings=Billingsella? laurentina.

Orthis lenticularis Wahlenberg?. **Upper Cam**

Orthis lenticularis (Wahl.) Kayser, Palæontographica, Suppl., III, 1876,
1, figs. 11, 12.—Matthew, Trans. Royal Soc. Canada, IX, 1892, p. 46,
figs. 9a–9d.
Loc. Province Salta and Jujuy, Argentine Republic; near St. John, New
wick.

Orthis lenticularis atrypoides Matthew. **Upper Cam**

Orthis lenticularis var. atrypoides Matthew, Trans. Royal Soc. Canada, I
p. 48, pl. 12, figs. 11a, 11b.
Loc. Near St. John, New Brunswick.

Orthis lenticularis lyncioides Matthew. **Upper Cam**

Orthis lenticularis var. lyncioides Matthew, Trans. Royal Soc. Canada, I
p. 49, pl. 12, figs. 10a–10c.
Loc. Near St. John, New Brunswick.

Orthis lenticularis strophomenoides Matthew. **Upper Cam**

Orthis lenticularis var. strophomenoides Matthew, Trans. Royal Soc. Cana
1892, p. 49, pl. 12, figs. 12a, 12b.
Loc. Near St. John, New Brunswick.

Orthis lenticularis Vanuxem=Dalmanella lenticularis.
Orthis lentiformis Hall=Dalmanella lenticularis.
Orthis lentiformis Owen=Schizophoria striatula.
Orthis leonensis Hall=Dalmanella tenuilineata.
Orthis lepida Hall=Dalmanella lepida.

Orthis (?) leptænoides Emmons. **Trenton (**

Orthis leptænoides Emmons, Geol. N. Y.; Rep. Fourth Dist., 1842, p. 396
Loc. New York.
Obs. Undefined and figure too poor for identification.

Orthis leucosia Hall=Rhipidomella leucosia.
Orthis limitaris Vanuxem=Leiorhynchus limitare.
Orthis linneyi James=Orthorhynchula linneyi.
Orthis livia Billings=Rhipidomella livia.
Orthis lonensis Walcott=Hebertella lonensis.
Orthis loricula Hall=Dinorthis deflecta.
Orthis lucia Billings=Rhipidomella lucia.
Orthis lynx Eichwald=Platystrophia lynx and P. biforata.
Orthis maria Billings=Hebertella maria.
Orthis macfarlanii Meek=Schizophoria macfarlanii.

Digitized by Google

Orthis macleodi Whitfield=Dalmanella macleodi.

Orthis macrior Sardeson=Dalmanella testudinaria emacerata.

Orthis media Shaler=Rhipidomella media.

Orthis media N. H. Winchell=Dalmanella subæquata pervetus.

Orthis meeki Miller=Dalmanella testudinaria meeki.

Orthis menapiæ Hicks. Calciferous (Ord.).

Orthis menapiæ (Hicks MS.) Davidson, Geol. Mag. London, V, 1868, p. 314, pl. 16, figs. 24–28.—Matthew, Trans. Royal Soc. Canada, X, 1893, p. 101, pl. 7, figs. 2–6.

Loc. England; near St. Johns, New Brunswick.

Orthis merope Billings=Scenidium merope.

Orthis michelini L'Éveillé=Rhipidomella michelini.

Orthis michelini Meek, 1877=Rhipidomella nevadaensis.

Orthis michelini burlingtonensis Hall=Rhipidomella burlingtonensis.

Orthis (?) minna Billings. Calciferous (Ord.).

Orthis minna Billings, Pal. Fossils, I, 1865, p. 303, fig. 294.

Loc. Stanbridge, Quebec, Canada.

Orthis minneapolis N. H. Winchell=Dalmanella subæquata.

Orthis minnesotensis Sardeson=Dinorthis meedsi.

Orthis missouriensis Shumard. Cape Girardeau Limestone (Sil.).

Orthis missouriensis Shumard, Geol. Rep. Missouri, 1855, p. 205, pl. C, fig. 9.—Keyes, Geol. Survey Missouri, V, 1895, p. 60.

Loc. Two miles above Cape Girardeau, Missouri.

Orthis missouriensis Swallow (non Shumard)=Rhipidomella missouriensis.

Orthis mitis Hall=Rhipidomella mitis.

Orthis morganiana Derby=Orthotichia morganiana.

Orthis (?) morrowensis James. Lorraine (Ord.).

Orthis (?) morrowensis James, Cincinnati Quart. Jour. Sci., I, 1874, p. 21.

Loc. Warren County, Ohio.

Orthis multisecta (James) Meek=Dalmanella multisecta.

Orthis multistriata Hall=Schizophoria multistriata.

Orthis musculosa Hall=Rhipidomella musculosa.

Orthis (?) mycale Billings. Calciferous (Ord.).

Orthis mycale Billings, Pal. Fossils, I, 1862, p. 82, fig. 75.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217, pl. 7A, figs. 10, 11.

Loc. Point Levis, Canada.

Orthis neglecta James=Plectorthis dichotoma.

Orthis nettoana Rathbun=Dalmanella nettoana.

Orthis nevadensis Meek=Rhipidomella nevadaensis.

Orthis (?) nisis Hall and Whitfield. Niagara (Sil.).

Orthis nisis Hall and Whitfield, Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 181;—Twenty-seventh Rep. Ibidem, 1875, pl. 9, figs. 4–8.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 42, pl. 27, figs. 4, 5.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217.

Loc. Louisville, Kentucky.

Orthis nucleus Hall=Ambocœlia umbonata.

Orthis oblata Hall=Rhipidomella oblata.

Digitized by Google

Orthis oblata emarginata Hall=Rhipidomella oblata emarginata.

Orthis obtusa Pander. Ordovi

Orthis obtusa (Pander) Kayser, Palæontographica, Suppl., III, 1876, p. 19, figs. 1, 2.

Loc. Europe; Cordillere San Juan, Argentine Republic.

Orthis occasus Hall=Rhipidomella occasus.

Orthis occidentalis Hall=Hebertella occidentalis.

Orthis orthambonites Billings=O. panderiana.

Orthis palmata Sharpe and Salter=Anoplotheca flabellites.

Orthis panderiana Hall and Clarke. Calciferous (C

Orthis orthambonites Billings (non Murchison and de Verneuil), Pal. Foss 1862, p. 77, fig. 70;—Geol. Canada, 1863, p. 231, fig. 245.—Schuchert, Ann. Rep. N. Y. State Geol., 1890, p. 43.—Hall and Clarke, Pal. New VIII, Pt. I, 1892, pp. 221, 228, pl. 5, figs. 1–3.—Matthew, Trans. Royal Canada, X, 1893, p. 101, pl. 7, fig. 4.

Orthis panderiana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, footnote.

Loc. Point Levis and St. John, Canada.

Orthis parva de Verneuil=Dalmanella elegantula.

Orthis pecosi Marcou=Rhipidomella pecosi.

Orthis (?) pectinata d'Orbigny. Devon

Orthis pectinatus d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., p. 39.

Spirifer pectinatus d'Orbigny, Ibidem, 1842, pl. 2, figs. 13–15.

Loc. Lake Titicaca, Bolivia.

Obs. Probably a species of Orthothetes.

Orthis pectinella Emmons=Dinorthis pectinella.

Orthis pectinella Whitfield, 1882=Plectorthis whitfieldi.

Orthis pectinella semiovalis Hall=Dinorthis pectinella.

Orthis peduncularis Hall=Schizophoria peduncularis.

Orthis peloris Hall=Rhipidomella peloris.

Orthis penelope Hall=Rhipidomella penelope.

Orthis penniana Derby=Rhipidomella penniana.

Orthis pennsylvanica Simpson=Rhipidomella pennsylvanica.

Orthis pepina Hall=Billingsella coloradoensis.

Orthis perelegans Hall=Dalmanella perelegans.

Orthis perversa Hall=Orthothetes chemungensis perversus.

Orthis perveta Conrad=Dalmanella subæquata pervetus.

Orthis perveta Hall, 1883=Dalmanella subæquata.

Orthis petræ Sardeson=Dinorthis proavita.

Orthis (?) pigra Billings. Chazy (C

Orthis piger Billings, Canadian Nat. Geol., IV, 1859, p. 442.

Loc. Mingan Island.

Obs. This species is probably congeneric with Billingsella grandæva.

Orthis pisum Hall (non Murchison)=Nucleospira pisiformis.

Orthis plana Castelnau (non Pander)=Rafinesquina alternata.

Orthis planoconvexa Hall=Dalmanella planiconvexa.

Orthis platys Billings=Dinorthis platys.

Orthis plicata Vanuxem=Spirifer vanuxemi.

Digitized by Google

Orthis plicatella White (non Hall)=Orthis tricenaria.
Orthis plicatella Hall=Plectorthis plicatella.
Orthis pogonipensis Hall and Whitfield=Dalmanella pogonipensis.
Orthis porcata McCoy=Dinorthis porcata.

Orthis (?) porcia Billings. Chazy (Ord.).

Orthis porcia Billings, Canadian Nat. Geol., IV, 1859, p. 439, figs. 16–18;—Geol. Canada, 1863, p. 130, fig. 58.
Loc. Near Montreal, Canada.

Orthis porrecta Sardeson=Dalmanella testudinaria porrecta.
Orthis præumbona Hall=Ambocœlia præumbona.
Orthis pratteni McChesney=Derbya pratteni.
Orthis pravus Hall=Orthothetes pravus.
Orthis propinqua Hall=Schizophoria propinqua.
Orthis propinqua Nettelroth=Schizophoria striatula.

Orthis (?) pumila Ulrich. Lorraine (Ord.).

Orthis costata (non Sowerby) Hall, American Jour. Sci., XLVIII, 1845, p. 295.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 33.
Orthis pumila Ulrich, Catalogue Cincinnati Fossils, 1880, p. 14.
Orthis cincinnatiensis Miller, American Pal. Fossils, 2d ed., 1883, p. 296.
Loc. Cincinnati, Ohio.

Orthis (?) punctostriata Hall. Niagara (Sil.).

Orthis punctostriata Hall, Pal. New York, II, 1852, p. 254, pl. 52, fig. 5.
Orthis? punctostriata Hall and Clarke, Ibidem, VIII, Pt. I, 1892, p. 217, pl. 20, figs. 2–4.
Loc. Lockport, New York.

Orthis pyramidalis Hall=Scenidium pyramidalis.
Orthis quacoensis Matthew=Billingsella quacoensis.
Orthis quadrans Hall=Dalmanella quadrans.
Orthis quadricostata Vanuxem=Leiorhynchus quadricostatum.

Orthis(?) remnicha N. H. Winchell. Upper Cambrian.

Orthis remnicha N. H. Winchell, Fourteenth Ann. Rep. Geol. Nat. Hist. Survey of Minnesota, 1886, p. 317, pl. 2, fig. 7.
Loc. Red Wing, Minnesota; Cold Creek Canyon, Burnett County, Texas.

Orthis resupinata Hall, 1843 (non Martin)=Schizophoria tulliensis.
Orthis resupinata Martin=Schizophoria resupinata.
Orthis resupinata latirostrata Toula=Schizophoria cora.
Orthis resupinoides Cox=Schizophoria resupinoides.
Orthis retrorsa Salter=Dinorthis retrorsa.
Orthis rhynchonelliformis Shaler=Rhipidomella rhynchonelliformis.
Orthis richmonda McChesney=Derbya crassa.
Orthis robusta Hall=Derbya robusta.
Orthis rogata Sardeson=Dalmanella testudinaria.

Orthis (?) rugiplicata Hall and Whitfield. Niagara (Sil.).

Orthis rugæplicata Hall and Whitfield, Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 182;—Twenty-seventh Rep. Ibidem, 1875, pl. 9, figs. 1–3.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 34, figs. 25–27.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 44, pl. 27, figs. 1–3.
Orthis rugiplicata, Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217.
Loc. Louisville, Kentucky.

Digitized by Google

Orthis (?) ruida Billings. **Anticosti (**

Orthis ruida Billings, Catalogue Silurian Fossils of Anticosti, 1866, p. 42.
Loc. Anticosti.

Orthis (?) saffordi Hall and Clarke. **Trenton (C**

Orthis ? saffordi, Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 21
pl. 5A, figs. 38–40.
Loc. "East Tennessee."

Orthis (?) salemensis Walcott. **Lower Camb**

Orthis salemensis Walcott, American Jour. Sci., 3d ser., XXXIV, 1887, p. 1
1, fig. 17;—Tenth Ann. Rep. U. S. Geol. Survey, 1891, p. 612, pl. 72, fig
Loc. Washington County, New York; near Quebec, Canada.

Orthis saltensis Kayser. **Upper Camb**

Orthis saltensis Kayser, Palæontographica, Suppl., III, 1876, p. 8, pl. 1, fig
Loc. Province Salta and Jujuy, Argentine Republic.

Orthis (??) sandbergeri N. H. Winchell. **Upper Camb**

Orthis sandbergeri N. H. Winchell, Fourteenth Ann. Rep. Geol. Nat. Hist.
vey of Minnesota, 1886, p. 318, pl. 2, figs. 8, 9.
Loc. Red Wing, Minnesota.

Orthis schohariensis Castelnau=Strophonella schohariensis.
Orthis scovilli Miller=Hebertella scovilli.
Orthis sectostriata Ulrich=Plectorthis sectistriata.
Orthis semele Hall=Rhipidomella semele.
Orthis sinuata Hall=Hebertella sinuata.

Orthis (?) sola Billings. **Lorraine (C**

Orthis sola Billings, Catalogue Silurian Fossils of Anticosti, 1866, p. 12.
Loc. Anticosti.

Orthis solitaria Hall=Rhipidomella solitaria.
Orthis stonensis Safford=Dalmanella stonensis.
Orthis striatocostata Geinitz=Meekella striaticostata.
Orthis striatula Emmons (non Schlotheim)=Dalmanella testudina
Orthis striatula of authors=Schizophoria striatula.
Orthis strophomenoides Hall=Orthostrophia strophomenoides.
Orthis subæquata Conrad=Dalmanella subæquata.
Orthis subcarinata Hall=Dalmanella subcarinata.
Orthis subcircula Simpson=Rhipidomella subcirculus.
Orthis subelliptica White and Whitfield=Rhipidomella subellipti
Orthis subjugata Hall=Hebertella occidentalis.

Orthis (?) subnodosa Hall. **Niagara (**

Orthis subnodosa Hall, Descriptions of n. sp. Fossils from Waldron, Indiana,
p. 14;—Eleventh Rep. State Geol. Indiana, 1882, p. 286, pl. 27, fig.
Trans. Albany Institute, X, 1883, p. 70.—Nettelroth, Kentucky Fossil S
Mem., Kentucky Geol. Survey, 1889, p. 44.
Loc. Waldron, Indiana; Louisville, Kentucky.

Orthis suborbicularis Hall=Rhipidomella suborbicularis.
Orthis subquadrata Hall=Dinorthis subquadrata.
Orthis subumbona Hall=Martinia subumbona.

Digitized by Google

sulivanti Morris and Sharpe. **Lower Devonian.**
sulivanti Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. , pl. 10, fig. 1.
ılkland Islands; South Africa.

'allovi Hall=Schizophoria swallovi.
'eeneyi Winchell=Dinorthis pectinella sweeneyi.

tenuidens Hall. **Clinton (Sil.).**
tenuidens Hall, Pal. New York, II, 1852, p. 58, pl. 20, fig. 9.
ıeida County, New York.
ıy be a species of Orthothetes.

enuis Morris and Sharpe. **Lower Devonian.**
tenuis Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 275, 10, fig. 4; pl. 11, fig. 4.
lkland Islands.
nilar to Chonostrophia complanata Hall.

tenuistriata Hall. **Portage (Dev.).**
enuistriata Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 245, fig. 3.
ores of Crooked Lake, New York.
is is not an Orthis; probably a pelecypod.

sus Sardeson=Dalmanella tersa.
tudinaria Dalman=Dalmanella testudinaria.
tudinaria Owen, 1844=O. tricenaria.
emii White=Rhipidomella thiemei.
ga Hall=Schizophoria tioga.

naria Conrad. **Trenton (Ord.).**
ricenaria Conrad, Proc. Acad. Nat. Sci. Philadelphia, I, 1843, p. 333.—, Pal. New York, I, 1847, p. 121, pl. 32, fig. 8.—Salter, Canadian Organic ıains, Decade I, 1859, p. 39, pl. 9, figs. 1–4.—Hall, Geol. Wisconsin, I, 1862, ?, figs. 8–11.—Billings, Geol. Canada, 1863, p. 167, fig. 151.—Hall, Second . Rep. N. Y. State Geol., 1883, pl. 35, figs. 1–5.—?Walcott, Mon. U. S. Geol. ⁄ey, VIII, 1884, p. 74, pl. 11, fig. 4.—Hall and Clarke, Pal. New York, VIII, [, 1892, pp. 191, 193, 221, 228, pl. 5, figs. 9–14.—Winchell and Schuchert, nesota Geol. Survey, III, 1893, p. 418, pl. 32, figs. 18–23.—Keyes, Geol. ⁄ey Missouri, V, 1895, p. 60, pl. 39, fig. 4.—Whiteaves, Pal. Foss., III, Pt. 1897, p. 175.
ısparilis Conrad, Proc. Acad. Nat. Sci. Philadelphia, I, 1843, p. 333.—, Pal. New York, I, 1847, p. 119, pl. 32, fig. 4.—Billings, Canadian Nat. ., IV, 1859, p. 440, fig. 20.—Hall, Geol. Wisconsin, I, 1862, p. 435.—Bill-, Geol. Canada, 1863, p. 130, fig. 60.—Hall and Clarke, Pal. New York, , Pt. I, 1892, pp. 191, 221, 228.
estudinaria? Owen, Geol. Expl. Iowa, Wisconsin, and Illinois, 1844, pl. ıg. 11.
plicatella White (non Hall), Wheeler's Expl. and Survey west 100th id., IV, 1875, p. 72, pl. 4, fig. 10.
ıeral Point, Wisconsin; Middleville, etc., New York; Kentucky; Ten-ee; near Ottawa and Montreal, Canada; Mingan Islands; Lake Winni-Manitoba; White Pine and Eureka districts, Nevada; Minneapolis, etc., ıesota; Pike County, Missouri.
plicatella White and O. tricenaria Walcott may prove to be distinct O. tricenaria Conrad.

Digitized by Google

Orthis (?) trinucleus Hall. Clinton (

Orthis trinucleus Hall, Pal. New York, II, 1852, p. 58, pl. 20, fig. 8.
Loc. Wayne County, New York.

Orthis triplicatella Meek=Plectorthis triplicatella.

Orthis (?) tritonia Billings. Calciferous (C

Orthis tritonia Billings, Pal. Fossils, I, 1862, p. 76, fig. 69;—Geol. Canada, p. 231, fig. 244.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p pl. 7A, figs. 12, 13.
Loc. Point Levis, Canada.

Orthis tubulostriata Hall=Rhipidomella tubulistriata.

Orthis tulliensis Vanuxem=Schizophoria tulliensis.

Orthis uberis Billings=Rhipidomella uberis.

Orthis umbonata Conrad=Ambocœlia umbonata.

Orthis umbraculum Owen (non von Buch)=Derbya robusta.

Orthis umbraculum Hall, 1852, Newberry, 1861=Orthothetes uml ulum.

Orthis unguiculus Hall, 1843 (non Phillips)=Ambocœlia gregaria.

Orthis unguiformis Castelnau, and Emmons=Hipparionyx proxim

Orthis vanuxemi Hall=Rhipidomella vanuxemi.

Orthis vanuxemi pulchella Herrick=Rhipidomella vanuxemi pulch

Orthis varica Conrad=Bilobites varicus.

Orthis vespertilio Sowerby. Ordovi

Orthis vespertilio (Sowerby) Kayser, Palæontographica, Suppl., III, 1876, pl. 3, figs. 22, 23.
Loc. Europe; Potrero de los Angulos, etc., Argentine Republic.

Orthis whitfieldi N. H. Winchell=Plectorthis whitfieldi.

Orthisina d'Orbigny=Clitambonites.

Orthisina alberta Walcott=Billingsella alberta.

Orthisina alternata Hall=Orthothetes chemungensis perversus.

Orthisina americana Whitfield=Clitambonites diversus.

Orthisina arctostriata Hall=Orthothetes chemungensis arctistriat

Orthisina crassa Meek and Hayden=Derbya crassa.

Orthisina diversa Shaler=Clitambonites diversus.

Orthisina festinata Billings=Billingsella festinata.

Orthisina grandæva Billings=Billingsella grandæva.

Orthisina missouriensis Swallow=Meekella striaticostata.

Orthisina transversa Walcott=Billingsella transversa.

Orthisina verneuili Billings=Clitambonites diversus.

ORTHORHYNCHULA Hall and C. Genotype Orthis (?) linneyi Ja

Orthorhynchula Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 181;— teenth Ann. Rep. N. Y. State Geologist, 1895, p. 824.

Orthorhynchula linneyi (James). Lorraine (O

Orthis (?) linneyi James, The Paleontologist, 5, 1881, p. 41.
Orthis linneyi Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Su 1889, p. 41, pl. 34, figs. 7–18; errata, p. 1.
Orthorhynchula linneyi Hall and Clarke, Pal. New York, VIII, Pt. II, 18 181, pl. 56, figs. 10–13, 19.
Loc. Near Danville, etc., Kentucky; Cincinnati, Ohio; Nashville, Tennes

Digitized by Google

ORTHOSTROPHIA Hall. Genotype Orthis strophomenoides Hall.

Orthostrophia Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, figs. 32–34.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 199, 223, 253;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 267.

Orthostrophia (?) fasciata Hall. Niagara (Sil.).

Orthis fasciata Hall, Pal. New York, II, 1852, p. 255, pl. 52, fig. 8.

Orthostrophia ? fasciata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 200, 223.

Loc. Rochester and Lockport, New York.

Orthostrophia strophomenoides Hall. Lower Helderberg (Dev.).

Orthis strophomenoides Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 46;—Pal. New York, III, 1859, p. 177, pl. 14, fig. 2.

Orthis halli Safford, Geol. Tennessee, 1869, pp. 328, 533.

Orthostrophia strophomenoides Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, figs. 32–34.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 200, 223, pl. 5A, figs. 24–27; pl. 6, figs. 32–34.

Orthostrophia halli Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 5A, figs. 22, 23.

Loc. Albany and Schoharie counties, New York; Square Lake, Maine; Perry County, Tennessee.

ORTHOTHETES Fischer de Wald. Genotype Spirifera crenistria Phil.

Orthothetes Fischer de Waldheim, Oryctographie du Gouvernement de Moscou, 1837, p. 133.—Waagen, Palæontologica Indica, Ser. XIII, I, p. 607, 1884.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 253;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 284.

Streptorhynchus Hall (non King), Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 61, figs. 1–6;—Pal. New York, IV, 1867, p. 64.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 139.

Orthothetes agassizi (Rathbun). Middle Devonian.

Streptorhynchus agassizi (Hartt) Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 248, pl. 9, figs. 3, 4, 10, 16, 17, 23, 25, 26, 28–30;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 24.

Loc. Erere, Province of Para, Brazil.

Orthothetes anomalus (A. Winchell). Hamilton (Dev.).

Crania (Pseudocrania) anomala A. Winchell, Geol. Rep. Lower Peninsula Michigan, 1866, p. 92.

Streptorhynchus anomala Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 152.

Loc. Grand Traverse region, Michigan.

Orthothetes bellulus Clarke. Marcellus (Dev.).

Orthothetes bellulus Clarke, Thirteenth Ann. Rep. N. Y. State Geologist, 1895, pp. 176, 187, pl. 4, figs. 2–4.

Loc. Livonia salt shaft, Livonia, New York.

Orthothetes chemungensis (Conrad). Chemung (Dev.).

Strophomena chemungensis Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 257, pl. 14, fig. 12.

Strophomena bifurcata Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 266, fig. 2.

Strophomena pectinacea Hall, Ibidem, 1843, p. 266, fig. 4.

Streptorhynchus chemungensis Hall, Pal. New York, IV, 1867, p. 67;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 40, fig. 9.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 117, pl. 13, fig. 16.

Streptorhynchus chemungensis var. pectinacea Hall, Pal. New York, IV, 1867, p. 73, pl. 10, fig. 6.

Digitized by Google

Orthothetes chemungensis (Conrad)—Continued.

Orthothetes chemungensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 255, pl. 10, fig. 9; pl. 11A, fig. 14.—Whiteaves, Cont. Canadian Pal., I, 1892, p. 285.

Loc. New York and Pennsylvania; Eureka district, Nevada; Lake Winnipegosis, Canada; Waverly group of Ohio.

Orthothetes chemungensis arctistriatus Hall. Hamilton (Dev.).

Strophomena arctostriata Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 266, fig. 3.

Orthisina arctostriata Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, pp. 80, 81, figs. 1, 2; p. 112.

Streptorhynchus chemungensis var. arctostriata Hall, Pal. New York, IV, 1867, p. 71, pl. 9, figs. 1-12;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 40, fig. 8.

Hemipronites chemungensis var. arctostriata Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 35, pl. 3, fig. 2.

Streptorhynchus arctostriata Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 117, pl. 13, fig. 7.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 140, pl. 31, figs. 31-33.

Orthothetes chemungensis var. arctostriata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 10, fig. 8.

Loc. New York; Falls of Ohio; Eureka district, Nevada.

Orthothetes chemungensis perversus (Hall). Cornif. and Ham. (Dev.).

Orthis perversa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 137.

Orthisina alternata Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 81, figs. 1, 2; p. 112.

Streptorhynchus chemungensis var. perversus Hall, Pal. New York, IV, 1867, p. 72, pl. 9, figs. 13-17, 26.

Streptorhynchus chemungensis var. alternata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 40, fig. 7.

Orthothetes chemungensis var. alternata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 10, fig. 7.

Loc. New York; Bosanquet, Ontario; Eureka district, Nevada.

Orthothetes crenistria (Phillips?). Lower Carboniferous.

Streptorhynchus crenistria? A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 410.

Streptorhynchus crenistria Davidson, Quart. Jour. Geol. Soc. London, XIX, 1863, p. 173, pl. 9, fig. 19.—Dawson, Acadian Geology, 3d ed., 1878, p. 296, fig. 96.—Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 362.

Hemipronites crenistria? Meek, Pal. Ohio, II, 1875, p. 279, pl. 10, fig. 5.

Hemipronites crenistria Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. pl. 7, fig. 2.—Herrick, Bull. Denison Univ., III, 1888, p. 37, pl. 5, fig. 14; pl. 3, fig. 24; pl. 6, fig. 8; pl. 9, fig. 21; IV, p. 24, pl. 2, figs. 1, 5;—Geol. Ohio, VII, 1895, pl. 15, fig. 1; pl. 21, fig. 14.

Orthothetes crenistria Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 255, pl. 11A, fig. 15.

Loc. Medina and Granville, Ohio; Port aux Barques, Michigan; East River and Shubenacadie, Nova Scotia; Feilden Isthmus, lat. 82° 43′; White Pine district, Nevada.

Obs. These references are unsatisfactory identifications of Phillips's species. It may prove that more than a single species is here included.

Orthothetes deformis Hall. Lower Helderberg (Dev.).

Orthis deformis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 44;—Pal. New York, III, 1859, p. 174, pl. 10A, fig. 13; pl. 15, fig. 3.

Digitized by Google

Orthothetes deformis Hall—Continued.

Streptorhynchus deformis Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 39, fig. 32.

Orthothetes deformis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 255, pl. 9, fig. 32.

Loc. Albany County, New York; Cumberland, Maryland.

Orthothetes deformis sinuatus Hall and Clarke. Lower Helderberg (Dev.).

Orthothetes deformis var. sinuata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 20, figs. 8, 9.

Loc. Cumberland, Maryland.

Orthothetes desideratus Hall and Clarke. Waverly (L. Carb.).

Orthothetes desideratus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 345, pl. 9A, figs. 26, 27.

Loc. Medina County, Ohio.

Orthothetes fiabellum (Whitfield). Corniferous (Dev.)

Streptorhynchus fiabellum Whitfield, Annals N. Y. Acad. Sci., II, 1882, p. 200;—Ibidem, V, 1891, p. 521, pl. 6, figs. 7, 9;—Geol. Ohio, VII, 1895, p. 421, pl. 2, figs. 7, 9.

Loc. Columbus, Ohio.

Orthothetes hydraulicus (Whitfield). Waterlime (Sil.).

Streptorhynchus hydraulicum Whitfield, Annals N. Y. Acad. Sci., II, 1882, p. 193;—Ibidem, V, 1891, p. 508, pl. 5, figs. 1–3;—Geol. Ohio, VII, 1895, p. 410, pl. 1, figs. 1–3.

Loc. Bellville and Greenfield, Ohio.

Orthothetes inæqualis Hall. Kinderhook (L. Carb.).

Orthis inequalis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 490, pl. 2, fig. 6.

Streptorhynchus inequalis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 117.

Streptorhynchus equivalvis Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 252, pl. 4, figs. 1, 2.

Streptorhynchus æquivalvis Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 42, figs. 20–23.

Orthothetes inæqualis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 9A, figs. 20–23.

Loc. Burlington, Iowa; Newark and Granville, Ohio; Shafers, Pennsylvania; Wasatch Range, Utah.

Orthothetes inflatus (White and Whitfield). Kinderhook (L. Carb.).

Streptorhynchus inflatus White and Whitfield, Proc. Boston Soc. Nat. Hist., VIII, 1862, p. 293.—Hall and Whitfield, King's U. S. Geol. Expl. 40 Parl., IV, 1877, p. 252, pl. 4, fig. 3.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 42, figs. 24, 25.

Orthothetes inflatus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 9A, figs. 24, 25.

Loc. Burlington, Iowa; Dry Canyon, Oquirrh Mountains, Utah; Montana.

Orthothetes interstriatus (Hall). Coralline (Sil.).

Orthis interstriata Hall, Pal. New York, II, 1852, p. 326, pl. 74, figs. 1, 2.

Loc. Schoharie, New York.

Orthothetes lens (White). Kinderhook (L. Carb.).

Streptorhynchus lens White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 28.—Keyes, Geol. Survey Missouri, V, 1895, p. 67, pl. 39, fig. 2.

Streptorhynchus lens? A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 117.

Digitized by Google

Orthothetes lens (White)—Continued.

Orthothetes lens Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 25
11A, figs. 16–22.

Loc. Clarksville, etc., Missouri; Hamburg, Illinois; Medina County, Ohio (
chell).

Orthothetes pandora (Billings). Upper Helderberg (D

Streptorhynchus pandora Billings, Canadian Jour., V, 1860, p. 226, figs. 12,
Geol. Canada, 1863, p. 369, fig. 384.—Nicholson, Pal. Prov. Ontario, 1874,

Streptorhynchus chemungensis var. pandora Hall, Pal. New York, IV, 186
68, pl. 4, figs. 11–19; pl. 9, figs. 18–25, 27;—Second Ann. Rep. N. Y.
Geol., 1883, pl. 40, figs. 1–6.

Orthothetes chemungensis var. pandora Hall and Clarke, Pal. New York,
Pt. I, 1892, p. 255, pl. 9, fig. 30; pl. 10, figs. 1–6.

Loc. Schoharie, Knoxville, Clarksville, etc., New York; Cayuga, Ont
Columbus, Ohio (Whitfield); Eureka district, Nevada.

Orthothetes pravus Hall. (?Upper) Devon

Orthis prava Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 490.

Orthothetes prava Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 25
11A, fig. 13.

Loc. Lime Creek, Worth County, Iowa.

Orthothetes subplanus (Conrad). Niagara and L. Held. (Sil. and D

Strophomena subplana Conrad, Jour. Acad. Nat. Sci., Philadelphia, VIII,
p. 258.—Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 104, fig. 1;—Tw
Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.

Leptæna subplana Hall, Pal. New York, II, 1852, p. 259, pl. 53, figs. 8–10.—Bill
Canadian Nat. Geol., I, 1856, p. 138, pl. 2, figs. 16, 17.

Strophomena pecten Roemer, Die Sil. Fauna west. Tennessee, 1860, p. 67,
fig. 4.—Billings, Geol. Canada, 1863, p. 311, fig. 315;—Catalogue Silurian
sils of Anticosti, 1866, p. 40.

Streptorhynchus (Strophodonta) subplanus Hall, Geol. Survey Wisconsi
1862, p. 436.

Streptorhynchus subplanus Hall, Trans. Albany Institute, IV, 1863, p. 2
Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 63, figs. 1, 2;—Tw
eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 151, pl. 21, figs. 26–
Eleventh Rep. State Geol. Indiana, 1882, p. 288, pl. 21, figs. 26–33;—Se
Ann. Rep. N. Y. State Geol., 1883, pl. 39, figs. 21–24; pl. 42, fig. 19.—Nettel
Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 141, p
figs. 11, 12.—Beecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 23,
figs. 14–20.

Streptorhynchus hemiaster Winchell and Marcy, Mem. Boston Soc. Nat. His
1865, p. 93, pl. 2, fig. 10.—Hall, Twentieth Rep. N. Y. State Cab. Nat.
1867, p. 392.

Hemipronites subplanus Meek and Worthen, Geol. Survey Illinois, III,
p. 349.

Hemipronites propinquus Meek and Worthen, Ibidem, III, 1868, p. 351, pl. 6,

Orthothetes subplana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p.
pl. 9, figs. 21–24; pl. 9A, fig. 19; pl. 11A, figs. 9–12.

Loc. Lockport, Rochester, etc., New York; Thorold, Ontario; Waldron, Indi
Louisville, Kentucky; Thebes, Alexander County, and Bridgeport, Illi
Pike County, Missouri; Decatur County, Tennessee; Arisaig, Nova S
(Ami); Anticosti.

Orthothetes tapajotensis (Derby). Upper Carbonifer

Streptorhynchus tapajotensis Derby, Bull. Cornell Univ., I, 1874, p. 37,
figs. 3, 6, 7, 9, 10; pl. 8. fig. 9.

Digitized by Google

Orthothetes tapajotensis (Derby)—Continued.

Orthothetes tapajotensis Waagen, Palæontologica Indica, Ser. XIII, I, 1884, pp. 607, 608.

Loc. Bomjardim and Itaituba, Brazil.

Orthothetes tenuis Hall. Niagara (Sil.).

Streptorhynchus tenuis Hall, Trans. Albany Institute, IV, 1863, p. 210;—Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 150, pl. 23, figs. 11–13;—Eleventh Rep. State Geol. Indiana, 1882, p. 287, pl. 23, figs. 11–13.—Foerste, Bull. Denison Univ., II, 1887, p. 105, pl. 8, figs. 31, 32, 38.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 142.

Orthothetes tenuis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 255.

Strophomena (Orthothetes) tenuis Foerste, Geol. Ohio, VII, 1895, p. 568, pl. 27, figs. 31, 32, 38.

Loc. Waldron, Indiana; near Louisville, Kentucky; Dayton, Ohio.

Orthothetes umbraculum of authors (non von Buch). L. and Up. Carb.

Orthis umbraculum Hall, Stansbury's Expl. Survey Valley Great Salt Lake, Utah, 1852, p. 412, pl. 3, fig. 6.—Newberry, Ives's Rep. Colorado River of the West, 1861, p. 125.

Streptorhynchus umbraculum? A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 117.

Hemipronites umbraculum? A. Winchell, Proc. American Philosophical Soc., XII, 1870, p. 251.

Orthothetes umbraculum Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 256.

Loc. Waverly group, Newark, Sciotoville, Warren, etc., Ohio; Up. Carb., Leavenworth, Kansas.

Orthothetes woolworthanus Hall. Lower Helderberg (Dev.).

Strophomena woolworthana Hall, Tenth. Rep. N. Y. State Cab. Nat. Hist., 1857, p. 48, figs. 1, 2;—Hall, Pal. New York, III, 1859, p. 192, pl. 17, figs. 1, 2.

Streptorhynchus woolworthana Billings, Geol. Canada, 1863, p. 957, fig. 449.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 39, figs. 25–31.

Orthothetes woolworthana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 255, pl. 9, figs. 25–31.

Loc. Schoharie, Carlisle, Clarksville, and Hudson, New York.

ORTHOTICHIA Hall and C. Genotype Orthis? morganiana Derby.

Orthotichia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 213;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 272.

Orthotichia morganiana (Derby). Upper Carboniferous.

Orthis? morganiana Derby, Bull. Cornell University, I, 1874, p. 29, pl. 3, figs. 1–9, 11, 34; pl. 4, figs. 6, 14, 15.

Orthis morganiana Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 564.

Orthotichia? morganiana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 213, 226, pl. 7, figs. 11–15.

Loc. Bomjardim and Itaituba, Brazil.

ORTHOTROPIA Hall and Clarke. Genotype O. dolomitica H. and C.

Orthotropia Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, explanation sheet to pl. 84, figs. 3–7.—Thirteenth Ann. Rep. N. Y. State Geol., 1895, p. 943.

Orthotropia dolomitica Hall and Clarke. Niagara (Sil.).

Orthotropia dolomitica Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 84, figs. 3–7.

Loc. Near Milwaukee, Wisconsin.

Digitized by Google

PARASTROPHIA Hall and C. Genotype Atrypa hemiplicata

Parastrophia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 221; teenth Ann. Rep. N. Y. State Geologist, 1895, p. 839.

Parastrophia divergens Hall and Clarke. Lorraine (

Parastrophia divergens Hall and Clarke, Pal. New York. VIII, Pt. II, 1895, 366, pl. 63, figs. 4–7.

Loc. Wilmington, Illinois.

Parastrophia greenei Hall and Clarke. Niagara

Parastrophia greenii Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, 367, pl. 63, figs. 17–20, 22.

Loc. Milwaukee, Wisconsin.

Parastrophia hemiplicata Hall. Trenton (

Atrypa hemiplicata Hall, Pal. New York, I, 1847, p. 144, pl. 33, fig. 10.—B Canadian Nat. Geol., I, 1856, p. 208, figs. 20–23.

Atrypa circulus Hall, Pal. New York, I, 1847, p. 142, pl. 33, fig. 7;—Twelft N. Y. State Cab. Nat. Hist., 1859, p. 65.

Pentamerus hemiplicatus Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist p. 66.—Billings, Canadian Jour., IV, 1859, p. 316.

Camarella hemiplicata Billings, Geol. Canada, 1863, p. 168, fig. 154.

Camarella circulus Miller, American Pal. Fossils, 1877, p. 107.

Camarella bernensis Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, pl. 4, figs. 4–6.

Anastrophia ? hemiplicata Winchell and Schuchert, Minnesota Geol. Surv 1893, p. 382, pl. 30, figs. 29–31.—Whiteaves, Pal. Foss., III, Pt. III, 1 167.

Parastrophia hemiplicata Hall and Clarke, Pal. New York, VIII, Pt. II, 1 221, pl. 63, figs. 1–3.

Loc. Middleville, Watertown, etc., New York; Center County, Pennsyl Wisconsin; Minnesota; Ottawa and Lake Winnipeg, Canada.

Parastrophia hemiplicata rotunda (Winchell and Schu.). Trenton (

Anastrophia ? hemiplicata var. rotunda W. and S., Minnesota Geol. Surv 1893, p. 383, pl. 30, figs. 32–35.

Loc. Cannon Falls, Minnesota; Decorah, Iowa.

Parastrophia latiplicata Hall and Clarke. Niagara

Parastrophia latiplicata Hall and Clarke, Pal. New York, VIII, Pt. II, 18 222, 368, pl. 63, figs. 23–27.

Loc. Milwaukee, Wisconsin.

Parastrophia multiplicata Hall and Clarke. Niagara

Parastrophia multiplicata Hall and Clarke, Pal. New York, VIII, Pt. I pp. 222, 367, pl. 63, figs. 15, 16, 21.

Loc. Milwaukee, Wisconsin.

Parastrophia (?) obscura (Hall and Whitfield). Pogonip (

Porambonites obscurus Hall and Whitfield, King's U. S. Geol. Expl. 40th IV, 1877, p. 234, pl. 1, fig. 16.

Porambonites ? obscurus Hall and Clarke, Pal. New York, VIII, Pt. II p. 228.

Loc. White Pine district, Nevada.

Obs. Based upon a single ventral valve which is insufficient to det whether it belongs to Parastrophia or some rhynchonelloid. It is Porambonites.

Digitized by Google

gs). Anticosti (Sil.).
Pal. Fossils, I, 1862, p. 148, fig. 128.

iety of P. reversa.

llings). Anticosti (Sil.).
Billings, Geol. Survey Canada; Rep. Progress for 1856,
dian Jour., IV, 1859, p. 316.
haler, Bull. Mus. Comp. Zool., 4, 1865, p. 69.
ler, American Pal. Foss., 1877, p. 104.
all and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 63,

pecies is a large P. hemiplicata Hall. It appears, how-
. See P. ops Billings.

Winchell and Schuchert). Trenton (Ord.).
W. and S., Minnesota Geol. Survey, III, 1893, p. 383, pl.

. Minnesota.

Clarke. Genotype Atrypa hirsuta Hall.
rke, Pal. New York, VIII, Pt. II, 1893, p. 127;—Thirteenth
te Geologist, 1895, p. 800.

Lower Helderberg (Dev.).
ll, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 89.
spira) deweyi Hall, Pal. New York, III, 1889, p. 216, pl.

nd Clarke, Ibidem, VIII, Pt. II, 1893, p. 128, fig. 112, pl.

arie counties, New York.

Corniferous and Hamilton (Dev.).
nth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 168.
Hall, Thirteenth Rep. Ibidem, 1860, p. 101;—Fourteenth
p. 101;—Fifteenth Rep. Ibidem, 1862, pl. 2, figs. 11-16;—
, 1867, p. 274, pl. 45, figs. 16-32.—Nettelroth, Kentucky
Kentucky Geol. Survey, 1889, p. 136, pl. 16, figs. 15-19.
, Canadian Jour., n. ser., V, 1860, p. 282, figs. 45-47.
Geol. Canada, 1863, p. 385, fig. 419.
Miller, Seventeenth Rep. State Geol. Indiana, 1892, p. 79,

nd Clarke, Pal. New York, VIII, Pt. II, 1895, p. 128, fig.
-39.
ord, Canada; Falls of Ohio; Bunker Hill, Indiana.

idea.

Genotype Paterula bohemica Barrande.
tème Sil. du Centre de la Bohéme, V, 1879, p. 110.—Hall
New York, VIII, Pt. I, 1892, pp. 78, 165;—Eleventh Ann.
ologist, 1894, p. 242.

Calciferous (Ord.).
nd Clarke, VIII, Pt. I, p. 78, pl. 4K, fig. 1.

Digitized by Google

PENTAGONIA Cozzens. Genotype Pentagonia peersii Cozzens= Atrypa unisulcata Conrad.

Pentagonia Cozzens, Annals Lyceum Nat. Hist. N. Y., IV, 1846, p. 158.—Meek and Hayden, Smithsonian Cont. Knowledge, XIV, 172, 1864, p. 16.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 80;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 775.

Goniocœlia Hall, Fourteenth Rep. N. Y. State Cab. Nat. Hist., 1861, p. 101.

Pentagonia peersii Cozzens=Pentagonia unisulcata.

Pentagonia unisulcata (Conrad). Oriskany to Hamilton (Dev.).

Atrypa unisulcata Conrad, Fifth Ann. Rep. Geol. Survey of N. Y., 1841, p. 56.—Hall, Fifteenth Rep. N. Y. State Cab. Nat. Hist., 1862, pl. 11, fig. 10.

Pentagonia peersii Cozzens, Annals Lyceum Nat. Hist. N. Y., IV, 1846, p. 158, pl. 10, fig. 3.

Rhynchonella unisulcata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 125.

Athyris? unisulcata Billings, Canadian Journal, V, 1860, p. 279, figs. 39–42.

Goniocœlia uniangulata Hall, Fourteenth Rep. N. Y. State Cab. Nat. Hist., 1861, p. 101.

Meristella ? unisulcata Hall, Fifteenth Rep. Ibidem, 1862, pl. 2, figs. 17–25.

Athyris unisulcata Billings, Geol. Canada, 1863, p. 373, fig. 396.

Meristella (Pentagonia) unisulcata varieties biplicata and uniplicata Hall, Pal. New York, IV, 1867, p. 309, pl. 50, figs. 18–35.

Meristella unisulcata Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 99, pl. 15, figs. 9–16.

Pentagonia unisulcata Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 80, pl. 42, figs. 22–32.

Loc. New York; county of Haldimand and Bosanquet, Ontario; Falls of Ohio.

PENTAMERELLA Hall. Genotype Atrypa arata Conrad.

Pentamerella Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 163;—Pal. New York, IV, 1867, pp. 373, 375.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 49.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 245;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 845.

Pentamerella arata (Conrad). Upper Helderberg (Dev.).

Atrypa arata Conrad, Fifth Ann. Rep. Geol. Survey N. Y., 1841, p. 55.

Atrypa octocostata Conrad, Ibidem, 1841, p. 55.

Pentamerus aratus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 120, figs. 1–10.—Billings, Canadian Journal, VI, 1861, p. 269, figs. 93–96;—Geol. Canada, 1863, p. 370, fig. 389.

Pentamerella arata Hall, Pal. New York, IV, 1867, p. 375, pl. 58, figs. 1–21.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 49, pl. 13, figs. 17–20.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 245, pl. 71, figs. 21–29.

? Pentamerus aratus Tschernyschew, Mém. Comité Géologique de St. Pétersbourg, III, 1887, p. 101, pl. 4, figs. 18, 19.

Loc. New York; Cayuga, etc., Ontario; Columbus, Ohio; Falls of Ohio; ? Urals of Russia.

Pentamerella borealis (Meek). Hamilton (Dev.).

Pentamerus borealis Meek, Trans. Chicago Acad. Sci., I, 1868, p. 95, pl. 13, fig. 11.

Loc. Anderson River, British America.

Pentamerella (?) compressa Ringueberg. Niagara (Sil.).

Pentamerella compressa Ringueberg, Bull. Buffalo Soc. Nat. Sci., V, 1886, p. 15, pl. 2, fig. 4.

Digitized by Google

Pentamerella (?) compressa Ringueberg—Continued.

Loc. Lockport, New York.

Obs. May be a pathologic or compressed specimen of Spirifer crispus or S. sulcatus.

Pentamerella dubia Hall. ? Hamilton (Dev.).

Atrypa (n. sp.?) Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 3A, fig. 1. [See specimen in U. S. Nat. Mus., Cat., Invert. Foss., 17927.]

Spirifer dubius Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 90.

Pentamerella dubia Hall, Pal. New York, IV, 1867, p. 379, pl. 58, figs. 38–43.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 245, pl. 71, figs. 32–38.

Loc. Iowa City, Iowa.

Obs. See Pentamerella micula Hall.

Pentamerella intralineata (A. Winchell). Hamilton (Dev.).

Pentamerus intralineatus A. Winchell, Geol. Rep. Lower Peninsula of Michigan, 1866, p. 94.

Loc. Grand Traverse region, Michigan.

Pentamerella micula Hall. ? Hamilton (Dev.).

Pentamerella micula Hall, Pal. New York, IV, 1867, p. 378, pl. 58, figs. 26, 27.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 245.

Loc. Iowa City, Iowa.

Obs. Compare with Pentamerella dubia Hall.

Pentamerella obsolescens Hall. ? Hamilton (Dev.).

Pentamerella obsolescens Hall, Pal. New York, IV, 1867, p. 379, pl. 58, figs. 24, 25.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 245.

Loc. Waterloo, Iowa.

Pentamerella pavilionensis Hall. Hamilton (Dev.).

Pentamerus papilionensis Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 86.

Pentamerella papilionensis Hall, Pal. New York, IV, 1867, p. 377, pl. 58, figs. 28–37.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 50.

Pentamerella pavilionensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 245, pl. 71, figs. 30, 31.

Loc. Seneca and Canandaigua lakes, etc., New York; Falls of Ohio.

Pentamerella thusnelda Nettelroth. Corniferous (Dev.).

Pentamerella thusnelda Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 51, pl. 31, figs. 26–28.

Loc. Near Louisville, Kentucky.

Pentamerella ventricosa Hall=Clorinda ventricosa.

PENTAMERUS Sowerby. Genotype P. lævis Sowerby.

Pentamerus Sowerby, Mineral Conchology, I, 1813, p. 76.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 236;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 844.

Pentamerus arcuosus McChesney=Clorinda arcuosa.

Pentamerus aratus=Pentamerella arata.

Pentamerus barrandi Billings=Clorinda barrandei.

Pentamerus beaumonti Castelnau=P. oblongus.

Pentamerus bisinuatus McChesney=P. oblongus.

Pentamerus borealis Meek=Pentamerella borealis.

Pentamerus brevirostris Hall=Anastrophia brevirostris.

Digitized by Google

Pentamerus chicagoensis Winchell and Marcy=Clorinda ventricosa.
Pentamerus colletti Miller=Conchidium colletti.
Pentamerus comis Meek and Worthen=Gypidula comis.
Pentamerus complanatus Nettelroth=Conchidium tenuicostatum.
Pentamerus conchidium=Conchidium biloculare.
Pentamerus coppingeri Etheridge=Gypidula coppingeri.
Pentamerus crassoradius McChesney=Conchidium crassiradiatum.
Pentamerus decussatus Whiteaves=Conchidium decussatum.
Pentamerus deshayessii Castelnau=Rensselæria ovoides.
Pentamerus elongatus Vanuxem=Amphigenia elongata.
Pentamerus fornicatus Hall=Clorinda fornicata.
Pentamerus galeatiformis Meek and Worthen=Gypidula comis.
Pentamerus galeatus Hall=Gypidula galeata.
Pentamerus galeatus Hall and Whitfield=Gypidula nucleus.
Pentamerus galeatus Roemer=Gypidula rœmeri.
Pentamerus globulosus Nettelroth=Gypidula globulosa.
Pentamerus hemiplicatus Billings=Parastrophia hemiplicata.
Pentamerus interplicatus Hall=Anastrophia interplicata.
Pentamerus intralineatus Winchell=Pentamerella intralineata.
Pentamerus knappi Hall and Whitfield=Conchidium knappi.
Pentamerus knighti Sowerby=Conchidium knighti.
Pentamerus knotti Nettelroth=Gypidula knotti.
Pentamerus laqueatus Conrad=Conchidium laqueatum.
Pentamerus lenticularis White and Whitfield=Camarophorella lenticularis.
Pentamerus littoni Hall=Conchidium littoni.
Pentamerus lotis Walcott=Gypidula lotis.
Pentamerus multicostatus=Conchidium multicostatum.
Pentamerus nobilis Emmons=Conchidium laqueatum.
Pentamerus nucleus Hall and Whitfield=Gypidula nucleus.
Pentamerus nysius var. crassicosta Hall=Conchidium nysius.
Pentamerus nysius var. tenuicostatus Nettelroth=Conchidium nysius.
Pentamerus nysius var. tenuicosta Hall=Conchidium tenuicosta.

Pentamerus oblongus Sowerby. Clinton and Niagara (Sil.).

Pentamerus oblongus Sowerby, Murchison's Silurian System, 1839, p. 641, pl. 19, fig. 10.—Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 70, figs. 1–5.—Owen, Geol. Expl. Iowa, Wisconsin and Illinois, 1844, pl. 14, fig. 10.—Hall, American Jour. Sci., 2d ser., XX, 1849, p. 227;—Pal. New York, II, 1852, p. 79, pl. 25, fig. 1; pl. 26, fig. 1.—Billings, Canadian Nat. Geol., I, 1856, p. 58, pl. 1, figs. 2, 3;—Geol. Canada, 1863, p. 316, fig. 326.—Hall and Whitfield, Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 183;—Geol. Survey Ohio, Pal., II, 1875, p. 137, pl. 7, fig. 9.—Whitfield, Geol. Wisconsin, IV, 1882, p. 288, pl. 17, figs. 4–9.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 60, pl. 33, figs. 15–17.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 237, figs. 169–171; pl. 67, fig. 20; pl. 68, figs. 1–5; pl. 69, figs. 1, 4-7, 13, 14; pl. 70, figs. 1–4.

Pentamerus beaumonti Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 38, pl. 13, fig. 9.

Digitized by Google

werby—Continued.

McChesney, Descriptions New Pal. Foss., 1861, p. 85;—
d. Sci., I, 1868, pl. 9, fig. 1.—Whitfield, Geol. Wisconsin,
17, fig. 3.

rk; Ohio; Indiana; Kentucky; Illinois; Iowa; Wiscon-
rio; Anticosti.

indricus Hall and Whitfield. Niagara (Sil.).

ar. cylindrica Hall and Whitfield, Twenty-fourth Rep.
Nat. Hist., 1872, p. 183;—Twenty-seventh Rep. Ibidem,
3, 14.—Nettelroth, Kentucky Fossil Shells, Mem. Ken-
, 1889, p. 61, pl. 30, figs. 2–4.—Hall and Clarke, Pal. New
1893, p. 237, fig. 172; pl. 68, figs. 7, 8; pl. 69, figs. 11, 12.
ky.

quoketa Hall and Clarke. Niagara (Sil.).

partim) Whitfield, Geol. Wisconsin, IV, 1882, pp. 288, 291,

ar. maquoketa Hall and Clarke, Pal. New York, VIII, Pt.
67, figs. 11–13.

n; near Dubuque and Hopkinton, Iowa.

rectus Hall and Clarke. Niagara (Sil.).

ar. subrectus Hall and Clarke, Pal. New York, VIII, Pt.
9, pl. 68, fig. 6; pl. 69, figs. 2, 3, 8–10; pl. 70, fig. 5.
Visconsin.

is Hall, 1858 (non 1852)=Gypidula comis.

is Hall, 1852=Conchidium occidentale.

Clinton (Sil.).

l, Pal. New York, II, 1852, p. 103, pl. 31, fig. 1.—Foerste,
Nat. Hist., XXIV, 1890, p. 324, pl. 5, figs. 17, 18.
neida County, New York; Cumberland Gap, Tennessee;
ma.

oblongus.

sis Hall=Pentamerella pavilionensis.

Hall and Whitfield. Niagara (Sil.).

s Hall and Whitfield, Pal. Ohio, II, 1875, p. 139, pl. 7, figs.
, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey,
and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 239, pl.

Louisville, Kentucky; Wisconsin (Whitfield).

tfield. Waterlime (Sil.).

hitfield, Annals N. Y. Acad. Sci., II, 1882, p. 195;—Ibidem,
5, figs. 11–22;—Geol. Ohio, VII, 1895, p. 414, pl. 1, figs.

Louisville, Kentucky; Wisconsin (Whitfield).

eatus Hall=Gypidula pseudogaleata.

Billings=Parastrophia reversa.

Swallow=Conchidium saliense.

us Meek and Worthen=Gypidula subglobosa.

s McChesney=Meristina trisinuata.

s Nettelroth=Gypidula uniplicata.

s Hall=Clorinda ventricosa.

Digitized by Google

Pentamerus verneuili Hall=Anastrophia verneuili.

PHOLIDOPS Hall. Genotype Orbicula squamiformis Hall.

Pholidops Hall, Pal. New York, III, 1859, p. 489;—Thirteenth Rep., N. Y. State Cab. Nat. Hist., 1860, p. 92;—Fifteenth Rep. Ibidem, 1862, p. 195;—Pal. New York, IV, 1867, pp. 31, 413.—Dall, Bull. Mus. Comp., Zool., III, 1871, p. 27.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 155.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 376.—Hall and Clarke, Eleventh Rep. N. Y. State Geologist, 1894, p. 262.

Craniops Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 84.—Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1272.

Pholidops arenaria Hall. Oriskany (Dev.).

Pholidops arenaria Hall, Pal. New York, IV, 1867, p. 413, pl. 3, fig. 10.—Hall and Clarke, Ibidem, VIII, Pt, I, 1892, pl. 4I, fig. 24.

Loc. Albany County and Hudson, New York.

Pholidops areolata Hall. Schoharie (Dev.).

Pholidops areolata Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 31;—Pal. New York, IV, 1867, p. 31, pl. 3, figs. 4, 5.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4I, figs. 25, 26.

Loc. Clarkeville and Knox, New York.

Pholidops bellula Walcott. Lower Devonian.

Pholidops bellula Walcott, Mon. U. S. Geol Survey, VIII, 1884, p. 113, pl. 2, fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 157.

Loc. Eureka district, Nevada.

Pholidops calceola Hall and Clarke. Corniferous (Dev.).

Pholidops calceola Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 157, 182, pl. 4I, fig. 30.

Loc. Falls of Ohio.

Pholidops cincinnatiensis Hall. Lorraine (Ord.).

Pholidops cincinnatiensis Hall, Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., 1872, pl. 7, fig. 10;—Pal. Ohio, I, 1873, p. 130, pl. 5, fig. 2.—Miller, Cincinnati Quart. Jour. Science, II, 1875, p. 14;—Jour. Cincinnati Soc. Nat. Hist., I, 1878, p. 107.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 157, pl. 4I, fig. 18.

Loc. Cincinnati, etc., Ohio.

Pholidops greenei Miller and Gurley. Hamilton (Dev.).

Pholidops greenei Miller and Gurley, Bull. Illinois State Mus. Nat. Hist., 12, 1897, p. 48, pl. 3, figs. 16–21.

Loc. Falls of Ohio.

Pholidops hamiltoniæ Hall. Hamilton (Dev.).

Pholidops hamiltoniæ Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 92;—Pal. New York, IV, 1867, p. 32, pl. 3, figs. 6–9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 157, pl. 4I, figs. 31–34 (37?).

Loc. Darien, Moscow, Canandaigua Lake, etc., New York.

Pholidops lamellosa Hall=Pholidops oblata.

Pholidops lepis Hall and Clarke. Corniferous (Dev.).

Pholidops lepis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 157.

Loc. Not given.

Obs. A nomina nudum.

Pholidops linguloides Hall=Pholidops oblata.

Digitized by Google

Hamilton (Dev.).

Pal. New York, IV, 1867, p. 414, pl. 3, fig. 10.
es Hall, Ibidem, 1867, p. 414.
ll, Ibidem, 1867, pl. 3, fig. 11.
nd oblata Hall and Clarke, Pal. New York, VIII, Pt. I,
gs. 35, 36.
daigua Lake, New York.

Niagara (Sil.).

Trans. Albany Institute, IV, 1863, p. 209;—Pal. New
3, figs. 1, 2;—Twenty-eighth Rep. N. Y. State Mus. Nat.
l. 21, figs. 1, 2;—Eleventh Rep. State Geol. Indiana, 1882,
1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,

: Arisaig, Nova Scotia (Ami).
. squamiformis are probably identical with P. implicata

Lower Helderberg (Dev.).

Pal. New York, III, 1859, p. 490, pl. 103B, fig. 7.
nd Clarke, Pal. New York, VIII, Pt. I, 1892, p. 157, pl. 4I,

ew York; † Square Lake, Maine.

d Clarke. Corniferous (Dev.).

nd Clarke, Pal. New York, VIII, Pt. I, 1892, p. 182, pl. 4I,

io.

is Walcott. Lower Devonian.

ris Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 114,

evada.
e of a crinoid.

Hall. Niagara (Sil.).

s Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 108, fig.
II, 1852, p. 250, pl. 53, fig. 4.
Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 84.
s Hall, Pal. New York, III, 1859, p. 490, pl. 103B, fig. 6.—
al. New York, VIII, Pt. I, 1892, p. 156, pl. 4I, fig. 21.
er, etc., New York.
is Hall.

all. Lorraine (Ord.).

Hall, Pal. New York, I, 1847, p. 290, pl. 79, fig. 7.
Hall, Descrip. n. sp. of Crinoidea and other Fossils, 1866,
rth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 221, pl. 7,
arke, Pal. New York, VIII, Pt. I, 1892, pl. 4I, fig. 19.
n, New York. In the Trenton at Ottawa, Canada (Ami).

l. Oriskany (Dev.).

Hall, Pal. New York, III, 1859, p. 490, pl. 103B, fig. 8.—
idem, VIII, Pt. I, 1892, p. 157.
rland.

all. Trenton (Ord.).

Hall, Descrip. n. sp. of Crinoidea and other Fossils, 1866,
rth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 221, pl. 7,
Clarke, Pal. New York, VIII, Pt. I, 1892, p. 157, pl. 4I,

York.

Digitized by Google

Pholidops trentonensis minor Winchell and Schuchert. Trenton (Ord.).

Pholidops trentonensis var. minor Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 376, pl. 29, fig. 40.

Loc. St. Paul and Cannon Falls, Minnesota.

PHOLIDOSTROPHIA Hall and Clarke. Genotype Strophodonta nacrea Hall=Chonetes (?) iowensis Owen.

Pholidostrophia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 287;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 281.

Pholidostrophia iowaensis (Owen). Corniferous and Hamilton (Dev.).

Chonetes (?) iowensis Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, p. 584, pl. 3A, fig. 7. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17942.]

Chonetes sp. undet. Owen, Ibidem, 1852, pl. 3A, fig. 17. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17916.]

Strophomena (Strophodonta) nacrea Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 144.

Strophomena lepida Hall, Geol. Iowa, I, 1858, p. 493, pl. 3, fig. 3.—Billings, Canadian Jour. Sci. Arts, VI, 1861, p. 344.

Strophodonta nacrea Hall, Pal. New York, IV, 1867, p. 104, pl. 18, fig. 1;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 46, figs. 20–24.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 146.

Strophеodonta (Pholidostrophia) nacrea Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 287, pl. 15, figs. 20–24; Pt. II, 1895, pl. 84, fig. 11.

Loc. Iowa City, Iowa; western New York; Columbus, Ohio; Falls of Ohio; Rock Island, Illinois; Alpena, Michigan; Ontario, Canada.

Obs. Owen's type specimens preserved in the United States National Museum prove to be identical with Strophomena lepida, which Hall in 1867 said is a synonym for Strophеodonta nacrea.

Plæsiomys Hall and Clarke=Dinorthis.

PLATYSTROPHIA King. Genotype Terebratulites biforata Schlotheim.

Platystrophia King, Mon. Permian Fossils of England, Pal. Soc., 1850, p. 116.—Hall, Geol. Soc. America, I, 1889, pp. 19, 20.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 200.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 454.—Hall and Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 268.

Obs. It is doubtful whether all the various forms of Platystrophia can be regarded as species. This genus is nearly always abundantly represented by one or more forms throughout the American Ordovician and Silurian systems. When individuals of the same region or of widely separated localities are compared with each other it is apparent that the specific characters are very inconstant. Individuals of a stratum, however, are fairly constant in form, size, and plications, and it is this limited constancy that has served in many of the following species.

Platystrophia acuminata James. Lorraine (Ord.).

Orthis (Platystrophia) acuminata James, The Palæontologist, 1, 1878, p. 7.

Loc. Cincinnati, Ohio.

Platystrophia acutilirata (Conrad). Lorraine (Ord.).

Delthyris acutilirata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 260, pl. 14, fig. 15.

Orthis (Platystrophia) acutilirata Meek, Pal. Ohio, I, 1873, p. 119, pl. 10, fig. 5.

Orthis acutilirata Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 28.

Digitized by Google

Platystrophia acutilirata (Conrad)—Continued.

Orthis biforata var. acutilirata White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, p. 487, pl. 2, figs. 5–9;—Tenth Rep. State Geol. Indiana, 1881, p. 119, pl. 2, figs. 5–9.

Platystrophia acutilirata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 223.

Loc. Richmond, Indiana; Oxford, Ohio; Louisiana, Missouri (Keyes).

Platystrophia biforata (Schlotheim). Chazy-Niagara (Ord. and Sil.).

Terebratulites biforatus Schlotheim, Petrefactenkunde, 1820, p. 265.

Spirifer sheppardi Castelnau, Essai Syst. Sil. l'Amérique Septentrionale, 1843, p. 42, pl. 14, fig. 15.

Delthyris brachynota Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 70, fig. 6.

Orthis and Delthyris Owen, Geol. Expl. Iowa, Wisconsin, Illinois, 1844, pl. 15, figs. 3, 7.

Delthyris lynx Hall (partim; non Eichwald), Pal. New York, I, 1847, p. 133, pl. 32D, fig. 1.

Spirifer biforata var. lynx Hall, Ibidem, II, 1852, p. 65, pl. 22, fig. 1.

Orthis biforatus Billings, Canadian Nat. Geol., I, 1856, p. 206, figs. 6–10.—Nicholson and Hinde, Canadian Jour., XIV, 1874, p. 158.—White, Rep. U. S. Geogr. Geol. Survey west 100th Meridian, IV, 1874, p. 74, pl. 4, fig. 9.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 35, pl. 29, figs. 18–29.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 312.

Orthis lynx Billings, Geol. Canada, 1863, p. 167, fig. 149.—Miller (partim), Cincinnati Quart. Jour. Sci., II, 1875, p. 25.

Platystrophia regularis Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 67.

Orthis (Platystrophia) biforata Meek, Pal. Ohio, I, 1873, p. 112.—Foerste, Geol. Ohio, VII, 1895, p. 579, pl. 25, figs. 7, 8.

Orthis (Platystrophia) biforata var. lynx Hall, Second Ann. Rep. N. Y. State Geologist, 1883, pl. 35, figs. 11–14 (non figs. 9, 10, 15 of pl. 35 and fig. 30, pl. 34=P. biforata lynx).

Orthis biforata var. lynx forma reversata and daytonensis Foerste, Bull. Denison Univ., I, 1885, pp. 81, 82, pl. 13, figs. 7, 8.

Platystrophia lynx Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 202, 223, pl. 5B, fig. 10.—Keyes, Geol. Survey Missouri, V, 1895, p. 64, pl. 39, fig. 5.

Platystrophia biforata Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 455, pl. 33, figs. 51–54.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 177.

Loc. Throughout the horizons mentioned above in North America; also in England, Scotland, Ireland, Gotland, Scandinavia, Oeland, and Russia.

Platystrophia crassa James. Lorraine (Ord.).

Orthis (Platystrophia) dentata?? Meek (non Pander), Pal. Ohio, I, 1873, p. 117, pl. 10, fig. 3.

Orthis (Platystrophia) crassa James, Cincinnati Quart. Jour. Sci., I, 1874, p. 20.

Orthis dentata Miller, Ibidem, II, 1875, p. 27.

Orthis centrosa Miller, North American Geol. Pal., 1889, p. 356.

Platystrophia crassa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 223.

Platystrophia biforata var. crassa Winchell and Schuchert, Geol. Survey Minnesota, III, 1893, p. 458, pl. 33, figs. 55, 56.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 178.

Loc. Cincinnati, Ohio; Spring Valley, Minnesota; Lake Winnipeg, Manitoba.

Platystrophia laticosta Meek. Lorraine (Ord.).

Orthis (Platystrophia) laticosta (James) Meek, Pal. Ohio, I, 1873, p. 116, pl. 10, fig. 4.

Orthis (Platystrophia) cypha James, Cincinnati Quart. Jour. Sci., I, 1874, p. 20.

Digitized by Google

Platystrophia laticosta Meek—Continued.

Orthis laticosta Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 27.

Platystrophia biforata var. laticosta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 223, pl. 5B, figs. 5–9

Loc. Cincinnati, etc., Ohio.

Platystrophia lynx (Eichwald). Lorraine (Ord.).

Terebratula lynx Eichwald, Skizze von Podolis, 1830, p. 202.

Delthyris lynx (partim) Hall, Pal. New York, I, 1847, p. 133, pl. 32D, fig. 1.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 820, fig. 616.

Orthis (Platystrophia) biforata var. lynx Meek, Pal. Ohio, I, 1873, p. 114, pl. 10, fig. 1.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 35, figs. 9, 10, 15.

Orthis lynx (partim) Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 25.

Orthis biforata Nicholson, Pal. Province Ontario, 1875, p. 16, fig. 5.

Orthis (Platystrophia) lynx Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 34, fig. 30.

Platystrophia biforata var. lynx Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 202, 223, pl. 5B, figs. 1–4.

Loc. Cincinnati, Ohio, and elsewhere in the Ohio Valley.

Platystrophia regularis Shaler=Platystrophia biforata.

PLECTAMBONITES Pander. Genotype P. planissima Pander.

Plectambonites Pander, Beitrage zur Geognosie des Russ. Reiches, 1830, p. 90, pl. 3, figs. 8, 16; pl. 28, fig. 19.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 236, 295.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 413.—Hall and Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 290.

Plectambonites arca Shaler=Plectambonites transversalis.

Plectambonites gibbosus Winchell and Schuchert. Trenton (Ord.).

Plectambonites gibbosa W. and S., American Geol., IX, 1892, p. 288;—Minnesota Geol. Survey, III, 1893, p. 416, pl. 32, figs. 13–17.

Loc. Mantorville, Old Concord, and near Cannon Falls, Minnesota.

Plectambonites glaber Shaler. Anticosti (Sil.).

Plectambonites glaber Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 64.

Leptæna glabra Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 294.

Loc. Anticosti.

Plectambonites plicatellus (Ulrich). Utica (Ord.).

Leptæna plicatella Ulrich, Jour. Cincinnati Soc. Nat. Hist., I, 1879, p. 15, pl. 7, fig. 12.

Plectambonites plicatella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15A, figs. 34, 35.

Loc. Cincinnati, Ohio; Covington, Kentucky.

Plectambonites productus Hall and Clarke. Niagara (Sil.).

Plectambonites producta Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 360, pl. 84, figs. 23–25.

Loc. Yellow Springs, Ohio.

Plectambonites sericeus (Sowerby). Trenton to Clinton (Ord.-Sil.).

Leptæna sericea J. de C. Sowerby, Murchison's Silurian System, 1839, pl. 19, figs. 1, 2.—Hall, Pal. New York, I, 1847, pp. 110, 287, pl. 31B, fig. 2; pl. 79, fig. 3;—Ibidem, II, 1852, p. 59, pl. 21, fig. 1.—Billings, Canadian Nat. Geol., I, 1856, p. 41, fig. 2.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 818, fig. 599.—Billings, Geol. Canada, 1863, p. 163, fig. 139.—Meek, Pal. Ohio, I, 1873, p. 70, pl. 5, fig. 3.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 57.—Kayser, Palæontographica, Suppl., III, 1876, p. 21, pl. 3, fig. 19.—Hall, Second Ann. Rep.

Digitized by Google

owerby)—Continued.

83, pl. 46, figs. 25–29.—Foerste, Proc. Boston Soc. Nat. . 293.—Keyes, Geol. Survey Missouri, V, 1895, p. 75, pl.

Wheeler's Expl. Survey west of the 100th Merid., IV, 7.

rad, Third Ann. Rep. Geol. Survey N. Y., 1840, p. 201.—; Rep. Second Dist., 1842, p. 394.

Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 47.

Cincinnati Quart. Jour. Sci., I, 1874, p. 151.

Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15,

ll and Schuchert, Minnesota Geol. Survey, III, 1893, p. 2.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 174.

Sardeson, Minnesota Acad. Nat. Sci., III, 1892, p. 329, pl.

on, Ibidem, 1892, p. 329, pl. 4, figs. 26–28.

son, Ibidem, 1892, p. 330, pl. 4, figs. 29–32.

, Ibidem, 1892, p. 330, pl. 4, figs. 33–35.

rk; Ohio; Indiana; Kentucky; Missouri; Wisconsin; a; Talacastra, Argentine Republic.

haler=Plectambonites transversalis.

lis (Wahlenberg). Clinton-Niagara (Sil.).

Wahlenberg, Act. Soc. Upsaliensis, III, 1821, p. 64.

Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 72, fig. 1.

lis Hall, Ibidem, 1843, p. 105, fig. 4.

Hall, Pal. New York, II, 1852, p. 256, pl. 53, fig. 5.—Bill- Geol., I, 1856, p. 138, pl. 2, figs. 14, 15.—Hall, Second e Geol., 1883, pl. 46, figs. 34–36.

tenera Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 64.

ar. elegantula Foerste, Proc. Boston Soc. Nat. Hist., l. 6, fig. 6.

salis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, –36.—Foerste, Geol. Ohio, VII, 1895, p. 566, pl. 25, fig. 5; fig. 6.

; Osgood, Indiana; Wisconsin; Dundas and Hamilton, Lake Temiscouata, New Brunswick.

lis alabamaensis (Foerste). Clinton (Sil.).

ar. alabamensis Foerste, Proc. Boston Soc. Nat. Hist., l. 5, fig. 9.

na.

lis prolongatus (Foerste). Clinton (Sil.).

rste, Bull. Denison Univ., I, 1885, p. 79, pl. 13, fig. 5.

ar. prolongata Foerste, Proc. Boston Soc. Nat. Hist., l. 5, fig. 13.

dwood Station, Georgia.

l Clarke. Genotype Orthis plicatella Hall.

atella) Hall, Bull. Geol. Soc. America, I, 1889, p. 20.

Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 194, 221.— chert, Minnesota Geol. Survey, III, 1893, p. 435.—Hall h Ann. Rep. N. Y. State Geologist, 1894, p. 266.

all). Lorraine (Ord.).

(non Davidson, 1847), Pal. New York, I, 1847, p. 120, pl.

Digitized by Google

Plectorthis æquivalvis (Hall)—Continued.

Plectorthis æquivalvis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p
221.

Loc. Cincinnati, Ohio; Wisconsin (Whitfield).

Plectorthis (?) aurelia (Billings). Oriskany (I

Orthis aurelia Billings, Pal. Fossils, II, 1874, p. 34, pl. 3, fig. 3.

Plectorthis ? aurelia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,

Loc. Indian Cove, Gaspé.

Plectorthis dichotoma Hall. Lorraine (

Orthis dichotoma Hall, Pal. New York, I, 1847, p. 125, pl. 32, fig. 13.—M
American Pal. Fossils, 1877, p. 117.

Orthis fissicosta Meek (non Hall), Pal. Ohio, I, 1873, p. 106, pl. 8, fig. 6.—M
Cincinnati Quart. Jour. Sci., II, 1875, p. 30.

Orthis neglecta James, The Palæontologist, 4, 1879, p. 26.

Plectorthis dichotoma Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,
pl. 5, fig. 21.

Loc. Cincinnati, Ohio.

Plectorthis ella Hall. Lorraine (

Orthis ella Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1861, p. 121.

Orthis ? ella Hall, Fifteenth Rep. Ibidem, 1862, pl. 2, figs. 6–8;—Twenty-
Rep. Ibidem, 1872, pl. 7, fig. 21.—Meek, Pal. Ohio, I, 1873, p. 105, pl.
9.—Hall and Whitfield, Ibidem, II, 1875, p. 76, pl. 1, fig. 20.—Miller
cinnati Quart. Jour. Sci., II, 1875, p. 32.

Plectorthis ? ella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 221,
figs. 22, 23.

Loc. Cincinnati, Ohio.

Plectorthis fissicosta Hall. Lorraine (

Orthis fissicosta Hall, Pal. New York, I, 1847, p. 121, pl. 32, fig. 7.

Plectorthis fissicosta Hall and Clarke, Pal. New York, VIII, Pt. I, 189
194, 221.

Loc. Cincinnati, Ohio.

Plectorthis jamesi Hall. Lorraine (

Orthis jamesi Hall, Fourteenth Rep. N. Y. State Cab. Nat. Hist., 1861, p.
Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 33.—Hall and Whi
Pal. Ohio, II, 1875, p. 77, pl. 1, figs. 21, 22.

Plectorthis jamesi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 19

Loc. Cincinnati, Ohio.

Plectorthis kankakiensis (McChesney). Lorraine (

Orthis kankakensis McChesney, New Pal. Fossils, 1861, p. 77;—Trans. Ch
Acad. Sci., I, 1868, p. 29, pl. 9, fig. 3.

Plectorthis kankakensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,
pl. 5, figs. 24, 25.

Loc. Wilmington, Illinois; Wisconsin (Whitfield).

Plectorthis plicatella Hall. Trenton-Lorraine (

Orthis plicatella Hall, Pal. New York, I, 1847, p. 122, pl. 32, fig. 9.—Meek
Ohio, I, 1873, p. 108, pl. 8, fig. 7.—Miller, Cincinnati Quart. Jour. Sc
1875, p. 30.

?Orthis plicatella Billings, Geol. Canada, 1863, p. 165, fig. 145.

Plectorthis plicatella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,
pl. 5, figs. 18–20.

Orthis (Plectorthis) plicatella Winchell and Schuchert, Minnesota Geol
vey, III, 1893, p. 436, pl. 33, figs. 5–7.

Loc. Cincinnati, Ohio; Middleville and Watertown, New York; Burgin,
tucky; Cannon Falls, Kenyon, etc., Minnesota; Wisconsin.

Digitized by Google

Plectorthis sectistriata (E. O. Ulrich). Lorraine (Ord.).

Orthis (?) sectostriata Ulrich, Jour. Cincinnati Soc. Nat. Hist., II, 1879, p. 15, pl. 7, fig. 11.

Plectorthis? sectostriata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 221.

Loc. Cincinnati, Ohio.

Plectorthis triplicatella (Meek). Lorraine (Ord.).

Orthis triplicatella Meek, American Jour. Sci., IV, 1872, p. 281;—Pal. Ohio, I, 1873, p. 109, pl. 8, fig. 8.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p 31.

Plectorthis triplicatella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 194, 221.

Loc. Cincinnati, Ohio.

Plectorthis whitfieldi (N. H. Winchell). Lorraine (Ord.).

Orthis whitfieldi N. H. Winchell, Ninth Ann. Rep. Geol. and Nat. Hist., Survey of Minnesota, 1881, p. 115.

Orthis pectinella Whitfield (partim, non Emmons non Hall), Geol. Wisconsin, IV, 1882, p. 259, pl. 12, fig. 8.

Plectorthis whitfieldi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 221, pl. 5, fig. 26.

Orthis (Plectorthis) whitfieldi Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 437, pl. 33, figs. 8–13.

Loc. Spring Valley and Granger, Minnesota; Delafield, Wisconsin; Lattners, Iowa; Savanna, Illinois.

PLETHORHYNCHA Hall and C. Genotype Rhynchonella speciosa Hall.

Plethorhyncha Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 191;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 827.

Obs. Proposed as a subgenus of Camarotœchia. It, however, does not seem to be worthy even of that rank. The species referred to Plethorhyncha are Camarotœchia barrandei Hall, C. pleiopleura (Conrad), and C. speciosa Hall.

Plicatula striatocostata Cox=Meekella striaticostata.

POLYTŒCHIA Hall and Clarke. Genotype Hemipronites apicalis Whitf.

Polytœchia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 239, figs. 11, 12;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 275.

Polytœchia apicalis (Whitfield). Calciferous (Ord.).

Hemipronites apicalis Whitfield, Bull. American Mus. Nat. Hist., II, 1886, p. 300, pl. 24, figs. 1–5.

Polytœchia apicalis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 239, fig. 11, 12, pl. 7A, figs. 26–30.

Loc. Fort Cassin, Vermont.

PORAMBONITES Pander. Genotype Porambonites intermedia Pander.

Porambonites Pander, Beitrage zur Geognosie des Russ. Reiches, 1830, p. 95, pl. 3, fig. 9.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 225.

Obs. Not represented in America.

Porambonites obscurus Hall and Whitfield=Parastrophia obscurus.

Porambonites ottawaensis Billings=Rhynchotrema ottawaensis.

PROBOSCIDELLA Œhlert. Genotype Productus proboscideus de Vern.

Proboscidella Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1277.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 333.

Proboscidella (?) clava (Norwood and Pratten). Upper Carboniferous.

Productus clavus Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 10, pl. 1, fig. 4.

Proboscidella clava Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 334.

Loc. Graysville, Illinois.

Digitized by Google

PRODUCTELLA Hall. Genotype Productus subaculeatus Murch

Productella Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 245; New York, IV, 1867, p. 153.—Nettelroth, Kentucky Fossil Shells, Mem tucky Geol. Survey, 1889, p. 69.—Hall and Clarke, Pal. New York, Pt. I, 1892, p. 328;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p.

Productella arctirostrata Hall. Chemung (I

Productus arctirostrata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857,

Productella arctirostrata Pal. New York, IV, 1867, p. 182, pl. 26, figs. 16 Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, fig. 36.—Hall and C Pal. New York, VIII, Pt. I, 1892, pl. 17, fig. 36.

Loc. Jasper and Cadiz, New York.

Productella arcuata Hall. Kinderhook (L. C

Productus arcuatus Hall, Geol. Survey of Iowa, I, Pt. II, 1858, p. 518, pl. 4.—Herrick, Bull. Denison Univ., III, 1888, p. 31, pl. 3, fig. 18.—Keyes Survey Missouri, V, 1895, p. 40.

Productella arcuata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 4 31, 32.

Loc. Burlington, Iowa; Granville, Newark, etc., Ohio; Hannibal, Missou

Obs. See P. cooperensis.

Productella bialveata Hall. Chemung (I

Productella bialveata Hall, Pal. New York, IV, 1867, p. 183, pl. 26, figs. 2

Loc. Meadville, Pennsylvania.

Productella boydi Hall. Chemung (I

Productus boydi Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, figs. 1–3.

Productella boydi Hall, Pal. New York, IV, 1867, p. 169, pl. 24, figs. 10 Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, fig. 24.—Hall and C Pal. New York, VIII, Pt. I, 1892, pl. 17, fig. 24.

Loc. Phillipsburg, Elmira, etc., New York.

Productella concentrica (Hall). Kinderhook (L. C

Productus concentricus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., p. 180;—Geol. Survey Iowa, I, Pt. II, 1858, p. 517, pl. 7, fig. 3.—A. Wi Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 411;—Ibidem, 1865, p. Proc. American Philosophical Soc., XII, 1870, p. 249.—Herrick, Bull. son Univ., III, 1888, p. 33, pl. 6, fig. 16.

Loc. Burlington, Iowa; Port aux Barques, Michigan; Rockford, Indiana; toville, etc., Ohio.

Obs. Compare with Productella shumardana.

Productella costatula Hall. Chemung (I

Productella costatula Hall, Pal. New York, IV, 1867, p. 180, pl. 26, figs. 9, Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, figs. 18–20, 35.—Ha Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, figs. 18–20, 35.

Loc. Randolph Conewango, New Albion, etc., New York.

Productella costatula strigata Hall. Chemung (I

Productella costatula var. strigata Hall, Pal. New York, IV, 1867, p. 181.

Loc. Near Cadiz, New York.

Productella dumosa Hall. Hamilton (I

Productus dumosus Hall, Fourteenth Rep. N. Y. State Cab. Nat. Hist., 1861,

Productella dumosa Hall, Pal. New York, IV, 1867, p. 162, pl. 23, figs. 38 Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, fig. 21.—Hall and C Pal. New York, VIII, Pt. I, 1892, pl. 17, fig. 21.

Loc. Delphi, Bellona, Moscow, Hamilton, etc., New York.

Digitized by Google

nolson. Corniferous (Dev.).
olson, Geol. Magazine London, n. ser., I, 1874, p. 118;—
74, p. 77, fig. 26.
lagersville, Ontario.
Hall.

lall. Corniferous and Hamilton (Dev.).
Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857,

Hall, Pal. New York, IV, 1867, p. 163, pl. 23, figs. 45,
p. N. Y. State Geol., 1883, pl. 48, fig. 17.—Hall and
k, VIII, Pt. I, 1892, pl. 17, fig. 17.
?? Meek and Worthen, Geol. Survey Illinois, III, 1868,

eneca Lake, New York; Jackson and Union counties,

tt. Upper Devonian.
(non de Koninck, 1846), Geol. Survey Iowa, I, Pt. II,
. 7.—Meek, Trans. Chicago Acad. Sci., I, 1868, p. 91,

n, 1868, p. 91, pl. 13, fig. 4.
allanus Walcott, Mon. U. S. Geol. Survey, VIII, 1884,

ernyschew, Mémoires du Comité Géologique de St.
, p. 114, pl. 14, fig. 27.—von Toll, Wissensch. Resultate
ed., 1885 u. 1886, 1889, p. 25, pl. 2, fig. 19.
iams, Bull. Geol. Soc. America, I, 1890, pl. 12, figs. 8, 9.
iteaves, Cont. Canadian Pal., I, 1891, p. 216.
and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17A,

gh Point, New York; Eureka district, Nevada; Atha-
Urals of Russia.

Chemung (Dev.).
a Vanuxem (non Productus membranaceus von Buch),
rd Dist., 1842, p. 179, figs. 4, 5.
Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 175,

Pal. New York, IV, 1867, p. 166, pl. 24, figs. 17–29;—
Y. State Geol., 1883, pl. 48, figs. 28, 39.—Hall and
k, VIII, Pt. I, 1892, pl. 17, figs. 28, 39, 45.
ckville, New York; Covington, Pennsylvania.

na Hall. Chemung (Dev.).
rectispina Hall, Pal. New York, IV, 1867, p. 168, pl. 24,
nn. Rep. N. Y. State Geol., 1883, pl. 48, fig. 37.—Hall
York, VIII, Pt. I, 1892, pl. 17, fig. 37.
ania.

Walcott). Upper Devonian.
alcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 133, pl.

ine districts, Nevada.

all=Strophalosia hystricula.

nrad). Chemung (Dev.).
Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII,
. 9.

Digitized by Google

Productella lachrymosa (Conrad)—Continued.

Productus lachrymosus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 177.
Productella lachrymosa Hall, Pal. New York, IV, 1867, p. 172, pl. 25, figs. 23–28.
Loc. Factoryville, Bath, Ellington, etc., New York.

Productella lachrymosa lima (Conrad). Chemung (Dev.).

Strophomena lima Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 256.
Productella lachrymosa var. lima Hall, Pal. New York, IV, 1867, p. 174, pl. 25, figs. 29–32;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, figs. 22, 23.—Whiteaves, Cont. Canadian Pal., I, 1891, p. 217.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, figs. 22, 23.
Productus (Productella) lachrymosus var. limus Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 132, pl. 13, fig. 18.
Loc. Randolph, Ellington, etc., New York; Eureka district, Nevada; Mackenzie River, Canada.

Productella lachrymosa stigmata Hall. Chem. and Wav. (Dev. and L. Car.).

Productella lachrymosa var. stigmata Hall, Pal. New York, IV, 1867, p. 174, pl. 25, figs. 33–41.
†Productus †Meek, Trans. Chicago Acad. Sci., I, 1868, p. 91, pl. 13, fig. 5.
Productus (Productella) lachrymosus var. stigmatus Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 132.—Herrick, Bull. Denison Univ., III, 1888, p. 34, pl. 3, fig. 28.
Loc. Olean, Conewango, and Randolph, New York; Licking County, Ohio; Eureka district, Nevada; Northwest Territory, Canada.

Productella mæcuruensis Rathbun. Middle Devonian.

Productella mæcuruensis Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 17.
Loc. Province of Para, Brazil.

Productella marquessi Rowley. Hamilton (Dev.).

Productella marquessi Rowley, American Geologist, XIII, 1894, p. 153, figs. 7, 8.
Loc. Callaway County, Missouri.

Productella minneapolis Sardeson=Trematis huronensis.

Productella murchisoniana (de Koninck). Hamilton (Dev.).

Productus murchisonianus de Koninck, Mém. de la Soc. Royale des Sciences de Liége, IV, 1846, p. 245, pl. 16, fig. 3.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 21.
Loc. Devils Back Bone, Illinois.

Productella navicella Hall. Corniferous and Hamilton (Dev.).

Productus navicellus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 172.
Productella navicella Hall, Pal. New York, IV, 1867, p. 156, pl. 23, figs. 1, 3, 9–11;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, figs. 8, 9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, figs. 8, 9;—Ibidem, VIII, Pt. II, 1895, pl. 84, fig. 19.
Productus (Productella) navicellus Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 131, pl. 13, fig. 9.
Loc. Schoharie County, Moscow, and Pavilion, New York; Eureka district, Nevada.

Productella onusta Hall. Chemung (Dev.).

Productella onusta Hall, Pal. New York, IV, 1867, p. 184, pl. 26, figs. 29–42;—Second Ann. Rep. N. Y. State Geologist, 1883, pl. 48, figs. 40–46.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, figs. 40–43, 46.
Loc. Conewango, Napoli, and New Albion, New York.

Digitized by Google

Productella papulata Hall. Hamilton (Dev.).

Productus papulatus Hall, Pal. New York, IV, 1867, p. 165, pl. 23, figs. 47, 48.

Productella papulata Hall, Ibidem, 1867, corrigenda.

Loc. Bellona, Yates County, New York.

Productella productoides (Murchison). Hamilton (Dev.).

Orthis productoides Murchison, Bull. Soc. Géol. de France, XI, 1840, p. 254, pl. 2, fig. 7.

Strophalosia productoides Whiteaves, Cont. Canadian Pal., I, 1889, p. 112, pl. 15, fig. 2;—Ibidem, I, 1891, p. 216.

Productella productoides Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 317.

Productella productoides var. membranacea Whiteaves, Cont. Canadian Pal., I, 1892, p. 282.

Loc. Europe; Athabasca River, Lake Manitoba, and Thedford, Canada.

Productella pyxidata Hall. Kinderhook (L. Carb.).

Productus pyxidatus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 498, pl. 3, fig. 8.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 130.

Productella pyxidata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, fig. 34.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, fig. 34; pl. 17A, fig. 14.—Keyes, Geol. Survey Missouri, V, 1895, p. 52.

Loc. Hamburg, Illinois; Louisiana, Missouri.

Obs. Compare with Productella shumardana.

Productella rarispina Hall. Chemung (Dev.).

Productus rarispinus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 178.

Productella rarispina Hall Pal. New York, IV, 1867, p. 170, pl. 24, figs. 1–9;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, fig. 33.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, fig. 33.

Loc. Phillipsburg, New York.

Productella semiglobosa Nettelroth. Corniferous (Dev.).

Productella semiglobosa Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 70, pl. 26, fig. 7.

Loc. Falls of Ohio.

Productella shumardana Hall. Kinderhook (L. Carb.).

Productus shumardianus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 499, pl. 3, fig. 9; pl. 7, fig. 2.

Productella shumardiana Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, fig. 7.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, fig. 7.

Productus (Productella) shumardianus Herrick, Bull. Denison Univ., III, 1888, p. 32, pl. 6, fig. 16; pl. 7, fig. 18.

Loc. Clarksville, Missouri; Burlington, Iowa; Licking County, Ohio.

Obs. The identifications of this species from Devonian horizons are here referred to P. spinulicosta. P. shumardana is probably synonymous with P. pyxidata Hall.

Productella speciosa Hall. Portage, Chem., and Kinderh. (Dev.-L. Carb.).

Productus speciosus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 176.

Producta speciosa A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 4.

Productella speciosa Hall, Pal. New York, IV, 1867, p. 175, pl. 25, figs. 1–11;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, figs. 25, 26.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, figs. 25, 26.—Kindle, Bull. American Pal., 6, 1896, p. 35.

Productus (Productella) speciosus Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 133, pl. 13, fig. 8.

Digitized by Google

Productella speciosa Hall—Continued.

Productus (Productella) speciosus? Herrick, Bull. Denison Univ., III, 188

Loc. Leon, New Albion, and Ithaca, New York; Licking County, Ohio; Bu ton, Iowa; Eureka district, Nevada.

Productella spinulicosta Hall. Corniferous to Hamilton (

Productus subaculeatus Norwood and Pratten (non Murchison), Jour. Aca Sci. Philadelphia, III, 1854, p. 21.—Meek, King's U. S. Geol. Expl. 40th IV, 1877, p. 36, pl. 3, fig. 7.

Productus subaculeatus? Meek, Simpson's Rep. Expl. Great Basin Terr. 1876, p. 345, pl. 1, fig. 3.

Productus spinulicostus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857,

Productella spinulicosta Hall, Pal. New York, IV, 1867, p. 160, pl. 23, fig 25–34;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, figs. 3–6.—Whit Cont. Canadian Pal., I, 1891, p. 217, pl. 29, fig. 3; pl. 31, fig. 1.—Ha Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, figs. 3–6.

Productella subaculeata Hall, Pal. New York, IV, 1867, p. 154, pl. 23, figs. Whiteaves, Cont. Canadian Pal., I, 1892, p. 283.—Hall and Clarke, Pa York, VIII, Pt. I, 1892, pl. 17, figs. 1, 2.

Productella subaculeata? Hall, Second Ann. Rep. N. Y. State Geol., 1883, figs. 1, 2.

Productus (Productella) subaculeata Walcott, Mon. U. S. Geol. Survey, 1884, pp. 128, 214, pl. 7, fig. 2; pl. 13, figs. 19, 20.

Productus (Productella) subaculeatus var. cataractus Hall and Whitfield, Tw fourth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 198;—Twenty-seventh Ibidem, 1875, pl. 9, figs. 9,10.

Productella subaculeata var. cataracta Nettelroth, Kentucky Fossil Shells, Kentucky Geol. Survey, 1889, p. 69, pl. 17, figs. 5–9.—Whiteaves, Canadian Pal., I, 1891, p. 217.

Loc. New York; Ohio; Falls of Ohio; Illinois; Iowa; Wisconsin; Eurel trict, Nevada; Utah; Mackenzie and Hay rivers, and Lake Manitoba, Ca

Obs. Some authors are disposed to regard as synonyms of this species, b the above, P. pyxidata, P. shumardana, and P. concentrica, and all of forms are thought to be identical with P. subaculeata Murchison. F present it is preferable to retain the name P. spinulicosta for these Am Devonian forms. P. pyxidata, P. shumardana, and P. concentrica ar arranged as species, but will probably be shown to be synonymou P. spinulicosta.

Productella striatula Hall. Chemung (

Productella striatula Hall, Pal. New York, IV, 1867, p. 177, pl. 25, figs. 14 Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, figs. 27, 38.—Ha Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17, figs. 27, 38, 44.

Loc. New Albion, Conewango, and Cold Spring, New York.

Productella subaculeata of American authors = Productella spinuli

Productella subaculeata cataracta Hall and Whitfield = Produ spinulicosta.

Productella subalata Hall. Middle Devo

Productus subalatus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. Geol. Survey Iowa, I, Pt. II, 1858, p. 500, pl. 3, fig. 10.

Productus callawayensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p.

Productella subalata Hall, Pal. New York, IV, 1867, p. 165, pl. 23, fig. 49; ond Ann. Rep. N. Y. State Geol., 1883, pl. 48, fig. 16.—Hall and Clark New York, VIII, Pt. I, 1892, pl. 17, fig. 16.—Keyes, Geol. Survey Mis V, 1895, p. 52.

Loc. Rock Island, Illinois; Callaway County, Missouri; Spring Valley, Minn

Digitized by Google

Productella truncata Hall=Strophalosia truncata.

Productella tullia Hall. Hamilton (Dev.).

Productella tullia Hall, Pal. New York, IV, 1867, p. 164, pl. 23, figs. 41–44.

Loc. Tully and Delphi Falls, New York.

PRODUCTUS Sowerby. Genotype Anomites productus Martin=Productus martini Sowerby=Productus semireticulatus (Martin).

Productus Sowerby, Mineral Conchology, I, 1814, p. 153.—de Koninck, Recher. Animaux Foss., Pt. I, 1847, p. 11.—Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 245;—Pal. New York, IV, 1867, p. 146.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 321;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 297.

Productus æquicostatus Shumard=Productus cora.

Productus alternatus Norwood and Pratten. Keokuk (L. Carb.).

Productus alternatus Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 20, pl. 2, fig. 1.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 49, fig. 14.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 18, fig. 14.

Productus vittatus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 639.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 18, figs. 15–17.—Keyes, Geol. Survey Missouri, V, 1895, p. 43.

Productus vittata Hall, Second Ann. Rep. N. Y. State Geologist, 1883, pl. 49, figs. 15–17.

Loc. Rocky Run, Hancock County, Illinois; Keokuk, Iowa; Burlington group, Burlington, Iowa.

Obs. Compare with Productus fimbriatus and P. gradatus.

Productus altonensis Norwood and Pratten. St. Louis (L. Carb.).

Productus altonensis Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 7, pl. 1, fig. 1.

Loc. Alton, Illinois.

Productus americanus Swallow=Productus cora.

Productus andii d'Orbigny=Orthis buchi.

Productus arctirostratus Hall=Productella arctirostrata.

Productus arcuatus Hall=Productella arcuata.

Productus asperus McChesney=Productus nebrascensis.

Productus auriculatus Swallow. ?Upper Carboniferous.

Productus auriculatus Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 92.

Productus (?auriculatus) Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17A, fig. 24.

Loc. Formation and locality not given. ("Near Kansas City, Missouri," H. and C.)

Productus batesianus Derby. Upper Carboniferous.

Productus batesianus Derby, Bull. Cornell Univ., I, 1874, p. 54, pl. 1, figs. 2, 10–13, 15; pl. 2, fig. 14; pl. 6, figs. 4, 7, 9.

Loc. Bomjardim and Itaituba, Brazil.

Productus biseriatus Hall. St. Louis (L. Carb.).

Productus biseriatus Hall, Trans. Albany Institute, IV, 1858, p. 12.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 46, pl. 6, figs. 8–12.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p, 325, pl. 29, figs. 8–12.—Keyes, Geol. Survey Missouri, V, 1895, p. 43.

Loc. Alton, Illinois; Bloomington and Spergen Hill, Indiana; Crittenden County, Kentucky; Missouri.

Digitized by Google

Productus blairi Miller. Chouteau (L. C

Productus blairi Miller, Seventeenth Rep. State Geol. of Indiana, 1891, p 13, figs. 16, 17.

Loc. Sedalia, Missouri.

Productus boliviaensis d'Orbigny. Upper Carbonif

Productus boliviensis d'Orbigny, Voyage dans l'Amériqne Méridionale 1842, p. 52, pl. 4, figs. 5–9.—de Koninck, Mém. de la Soc. Royale des Sci. IV, 1847, p. 177, pl. 8, fig. 2;—Recherches sur les Animaux Fossiles, Pt. p. 76, pl. 8, fig. 2.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philad III, 1854, p. 11.

Productus cancrini Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., VII p. 302.

Loc. Yarbichambi and Lake Titicaca, Bolivia; near Richmond, Missouri.

Productus boonensis Swallow. Upper Carbonif

Productus boonensis Swallow, Trans. St. Louis Acad. Sci., I, 1858, p. 217.

Loc. Near the mouth of Platte River; Kansas and Missouri.

Obs. Compare with Productus undiferus de Koninck.

Productus boonensis elevata Swallow. Upper Carbonif

Productus boonensis var. elevata Swallow, Trans. St. Louis Acad. Sci., p. 217.

Loc. Near the mouth of Platte River, Missouri.

Productus boydi Hall=Productella boydi.

Productus buchianus de Koninck. Upper Carbonif

Productus buchianus de Koninck, Recherches sur les Animaux Fossiles 1847, p. 129, pl. 18, fig. 4.—Norwood and Pratten, Jour. Acad. Na Philadelphia, III, 1854, p. 20.

Loc. Belgium; Big Creek, Posey County, Indiana.

Productus burlingtonensis Hall. Burlington (L. C

Productus flemingi var. burlingtonensis Hall, Geol. Survey Iowa, I, Pt. I p. 598, pl. 12, fig. 3.—Hall and Whitfield, King's U. S. Geol. Expl. 40th IV, 1877, p. 265, pl. 5, figs. 9–12.—Hall, Second Ann. Rep. N. Y. State 1883, pl. 49, figs. 6–8.—Herrick, Bull. Denison Univ., III, 1888, p. 32 figs. 20 (?22).—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, figs. 6–8.

Productus burlingtonensis Keyes, Geol. Survey Missouri, V, 1895, p. 41.

Loc. Burlington, Iowa; Quincy, Illinois; Missouri; Oquirrh Mountains,

Obs. Compare with P. mesialis.

Productus calhounianus Geinitz (non Swallow)=Productus cora.

Productus calhounianus Swallow=Productus semireticulatus.

Productus calhounianus kansasensis Swallow=Productus semiret tus kansasensis.

Productus callawayensis Swallow=Productella subalata.

Productus cancrini Geinitz=Productus pertenuis.

Productus cancrini Gabb=P. boliviaensis.

Productus capacii d'Orbigny. Upper Carbonife

Productus capacii d'Orbigny, Voyage dans l'Amérique Méridionale, Pal. p. 50, pl. 3, figs. 24–26.

Loc. Yarbichambi, Bolivia.

Digitized by Google

Productus carbonarius de Koninck. Carboniferous.

Productus carbonarius de Koninck, Description Animaux Fossiles, 1844, p. 181, pl. 12 bis, fig. 1.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 11.

Loc. Belgium; Fountain Bluff, Illinois.

Productus cestriensis Worthen=Productus fasciculatus.

Productus chandlessii Derby. Upper Carboniferous.

Productus chandlessii Derby, Bull. Cornell Univ., I, 1874, p. 51, pl. 4, figs. 1–4, 7, 9–11, 13, 16; pl. 6, fig. 1;—Bull. Mus. Comp. Zool., III, 1876, p. 280.

Loc. Itaituba, Brazil; Yampopata, Bolivia.

Obs. Compare with Productus boliviaensis d'Orbigny.

Productus clarkianus Derby. Upper Carboniferous.

Productus clarkianus Derby, Bull. Cornell Univ., I, 1874, p. 59, pl. 6, fig. 6; pl. 9, figs. 12, 13.

Loc. Itaituba and Bomjardim, Brazil.

Productus clavus Norwood and Pratten=Proboscidella clava.

Productus concentricus Hall=Productella concentrica.

Productus confragosus Conrad. Upper Carboniferous.

Productus confragosus Conrad, Trans. Geol. Soc. Pennsylvania, I, 1835, p. 268, pl. 12, fig. 5.

Loc. Alleghany Mountains, Pennsylvania.

Obs. Not well established.

Productus cooperensis Swallow. Kinderhook (L. Carb.).

Productus cooperensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 640.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 115.

Productus cooperensis? A. Winchell, Proc. American Philosophical Soc., XII, 1870, p. 249.

Loc. Cooper County, Missouri; Burlington, Iowa; Sciotoville, Ohio.

Obs. Keyes regards this species as a synonym for Productella arcuata.

Productus cora d'Orbigny. Upper Carboniferous.

Productus cora d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 55, pl. 5, figs. 8–10.—de Koninck, Recherches sur les Animaux Fossiles, Pt. I, 1847, p. 50, pl. 4, fig. 4; pl. 5, fig. 2.—Owen, Geol. Rep. Wisconsin, Iowa, and Minnesota, 1852, pp. 103, 136, pl. 5, fig. 1.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 6.—Marcou, Geol. North America, 1858, p. 45, pl. 6, fig. 4.—Davidson, Quart. Jour. Geol. Soc. London, XIX, 1863, p. 174, pl. 9, figs. 22, 23.—Geinitz, Carbon und Dyas in Nebraska, 1866, p. 50.—Derby, Bull. Mus. Comp. Zool., III, 1876, p. 281.—Dawson, Acadian Geology, 3d ed., 1878, p. 297, fig. 98.—Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 677.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 126, pl. 26, figs. 1–3.—Herrick, Bull. Denison Univ., II, 1887, p. 47, pl. 2, fig. 26.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 227;—Geol. Survey Missouri, V, 1895, p. 47, pl. 37, fig. 2.

Productus cfr. cora Toula, Sitzb. der k. k. Akad. der Wissensch. zu Wien, LIX, 1869, p. 9.

Productus cora? Derby, Bull. Cornell Univ., I, 1874, p. 49, pl. 2, fig. 17; pl. 6, fig. 17.

Productus lyelli de Verneuil, Lyell's Travels in North America, II, 1845, p. 221.—Dawson, Acadian Geology, 1855, p. 219, fig. g.

Productus sp. Christy, Letters on Geology, 1848, pl. 5, fig. 1.

Digitized by Google

Productus cora d'Orbigny—Continued.

Productus semireticulatus Hall, Stansbury's Expl. and Survey Valley Gre
Lake, Utah, 1852, p. 411, pl. 3, figs. 3, 5.

Productus prattenianus Norwood, Jour. Acad. Nat. Sci. Philadelphia, II
p. 17, fig. 10.—Meek, Final Rep. U. S. Geol. Survey of Nebraska, 1872,
pl. 2, fig. 5; pl. 5, fig. 13; pl. 8, fig. 10.—White, Wheeler's Expl. and
west 100th Meridian, IV, 1875, p. 113, pl. 7, fig. 1.—Meek, King's U. S
Expl. 40th Parl., IV, 1877, p. 72, pl. 7, fig. 7.

Productus æquicostatus Shumard, Geol. Rep. Missouri, I, 1855, p. 201, Pl
10.—Schiel, Pacific R. R. Reports, II, 1855, p. 108, pl. 2, figs. 4, 5.—Ha
Clarke, Pal. New York, VIII, Pt. I, 1892, figs. 22, 23.

Productus pileiformis McChesney, New Pal. Fossils, 1860, p. 40.—Whi
Annals N. Y. Acad. Sci., V, 1891, p. 582, pl. 13, figs. 13, 14;—Geol. Ohi
1895, p. 470, pl. 9, figs. 13, 14.

Productus americanus Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 9

Productus flemingi Geinitz (non de Koninck), Carbon und Dyas in Neb
1866, p. 52, pl. 4, figs. 1–4.

Productus koninckianus Geinitz (non de Verneuil), Ibidem, 1866, p. 53, pl. 4

Productus calhounianus Geinitz (non Swallow), Ibidem, 1866.

Loc. Throughout the Upper Carboniferous of North America; Itaitub
Barreirinha, Brazil; Yampopata, Cochabamba, and Lake Titicaca, Bo
Kashmere.

Obs. See Productus nodosus and P. hildrethianus.

Productus cora mogoyoni Marcou. Upper Carbonife

Productus cora var. mogoyoni Marcou, Geol. North America, 1858, p. 45,
fig. 5.

Loc. Sierra de Mogoyn, or Sierra Blanca, near the extinct volcano San Fra
Arizona.

Productus coriformis Swallow. St. Louis (L. C

Productus coræformis Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 94

Loc. Cooper County, Missouri.

Obs. Keyes regards this species as a synonym for P. lævicostus.

Productus costatoides Swallow. Upper Carbonife

Productus costatoides Swallow, Trans. St. Louis Acad. Sci., I, 1858, p.
Newberry, Ives's Rep. Colorado River of the West, 1861, p 123.

Loc. Kansas; banks of Colorado River.

Obs. Keyes regards this species as identical with P. longispinus.

Productus costatus (Sowerby ?) de Koninck. Upper Carbonife

?Productus costatus Sowerby, Mineral Conchology, VI, 1827, p. 115, p
fig. 1.

Productus costatus de Koninck, Recherches sur les Animaux Fossiles,
1847, p. 92, pl. 8, fig. 3; pl. 10, fig. 3; pl. 18, fig. 3.—Norwood and Pr
Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 11.—Marcou, Geol.
America, 1858, p. 46, pl. 5, fig. 5.—Geinitz, Carbon und Dyas in Neb
1866, p. 51.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 159
fig. 6.—White, Wheeler's Expl. and Survey West 100th Meridian, IV,
p. 109, pl. 8, fig. 2;—Second Ann. Rep. Indiana Bureau of Statistic
Geol., 1880, p. 516, pl. 8, figs. 7, 8;—Tenth Rep. State Geol. Indiana,
p. 148, pl. 8, figs. 7, 8.—Hall, Second Ann. Rep. N. Y. State Geol.,
pl. 50, figs. 8–13.—White, Thirteenth Rep. State Geol. Indiana, 1884, p
pl. 24, figs. 4–6; pl. 25, figs. 3–5.—Hall and Clarke, Pal. New York, VIII,
1892, pl. 19, figs. 8–13.—Keyes, Geol. Survey Missouri, V, 1895, p. 51,
fig. 1.

Digitized by Google

Productus costatus (Sowerby?) de Koninck—Continued.

Productus costatus? Derby, Bull. Mus. Comp. Zool., III, 1876, p. 280.

Productus costatus var. Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 712, pl. 28, figs. 3, 4.—Meek, King's U. S. Geol. Expl. 40th, Parl., IV, 1877, pl. 7, fig. 4.

Productus portlockianus Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 15, pl. 1, fig. 9.

Productus sp. Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 833, fig. 687.

Productus viminalis White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 29.

Loc. Europe; throughout the Upper Carboniferous of North America; Yampopata, Bolivia.

Obs. Sowerby's species is of uncertain value. The above synonomy is based upon P. costatus as redefined and illustrated by de Koninck.

Productus curtirostratus A. Winchell. Kinderhook (L. Carb.).

Producta curtirostra A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 114.

Productus curtirostratus Miller, N. American Geol. Pal., 1889, p. 364.

Loc. Burlington, Iowa.

Productus delawarei Marcou. Carboniferous.

Productus delawarii Marcou, Geol. North America, 1858, p. 45, pl. 5, fig. 3.

Loc. Foot of Delaware Mountain, Texas.

Obs. Compare with Productus cora d'Orbigny.

Productus depressus Swallow. Keokuk (L. Carb.).

Productus depressus Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 93.

Loc. Fenton, St. Louis County, Missouri.

Productus dissimilis Hall (non de Koninck)=Productella hallana.

Productus dolorosus A. Winchell. Waverly (L. Carb.).

Productus dolorosus A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 114.

Loc. Weymouth, Medina County, Ohio.

Productus dumosus Hall=Productella dumosa.

Productus duplicostatus A. Winchell. Waverly (L. Carb.).

Productus duplicostatus A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 113.—Herrick, Bull. Denison Univ., IV, 1888, p. 21, pl. 11, figs. 26, 29.

Loc. Knox and Licking counties, Ohio; Battlecreek, Michigan.

Productus elegans Norwood and Pratten (non McCoy)=Productus fasciculatus.

Productus exanthematus Hall=Productella exanthemata.

Productus fasciculatus McChesney. Kaskaskia (L. Carb.).

Productus elegans Norwood and Pratten (non McCoy), Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 13, fig. 7.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 581, pl. 13, figs. 15–16;—Geol. Ohio, VII, 1895, p. 469, pl. 9, figs. 15, 16.

Productus fasciculatus McChesney, New Pal. Fossils, 1860, p. 38.

Productus cestriencis Worthen, Trans. St. Louis Acad. Sci., I, 1860, p. 570.—Keyes, Geol. Survey Missouri, V, 1895, p. 44.

?Productus elegans Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 268, pl. 5, figs. 3, 4.

Loc. Chester and Kaskaskia, Illinois; Leavenworth and Washington County, Indiana; Missouri; Monongalia County, West Virginia; Caldwell County, Kentucky; Newtonville, Ohio; ?Oquirrh Mountains, Utah.

Digitized by Google

Productus fentonensis Swallow. Keokuk (L. Carb.).

Productus fentonensis Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 93.

Loc. Fenton, St. Louis County, Missouri.

Obs. Keyes says this is a synonym for P. magnus.

Productus fimbriatus Sowerby. ?St. Louis. ?Upper Carboniferous.

Productus fimbriatus Sowerby, Mineral Conchology, V, 1824, p. 85, pl. 459, fig. 1.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 19.—Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 630.

Loc. Alton, Illinois; Posey County, Indiana; Feilden Isthmus, lat. 82° 43′.

Obs. Compare with Productus alternatus Norwood and Pratten.

Productus flemingi Geinitz (non de Koninck)=Productus cora.

Productus flemingi Marcou, and Roemer=Productus longispina.

Productus flemingi burlingtonensis Hall=Productus burlingtonensis.

Productus flexistria McCoy. Kaskaskia (L. Carb.).

Productus flexistria McCoy, Synopsis Carb. Fossils of Ireland, 1844, p. 109, pl. 20, fig. 16.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 6.

Loc. Chester, Kaskaskia, and Fountain Bluff, Illinois; Stephensport, Kentucky.

Productus giganteus (Martin). Upper Carboniferous.

Anomites giganteus Martin, Petrefacta Derbiensia, 1809, p. 6, pl. 15, fig. 1.

Productus giganteus White, Proc. U. S. Nat. Mus., III, 1880, p. 46;—Twelfth Ann. Rep. U. S. Geol. Survey of the Terr., 1883, p. 132, pl. 36, fig. 1.

Loc. Europe; McCloud River, Shasta County, California.

Productus gracilis A. Winchell. Waverly (L. Carb.).

Productus gracilis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 112.—Herrick, Bull. Denison Univ., III, 1888, p. 34, pl. 7, fig. 2.

Productus gracilis? A. Winchell, Proc. American Philosophical Soc., XII, 1870, p. 250.

Loc. Near Cuyahoga Falls, Sciotoville, and Granville, Ohio.

Productus gradatus Swallow. Keokuk (L. Carb.).

Productus gradatus Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 93.

Loc. Keokuk, Iowa; Lewis and St. Louis counties, Missouri.

Obs. Keyes regards this species as identical with P. vittatus=P. alternatus.

Productus granulosus Phillips. Keokuk (L. Carb.).

Productus granulosus Phillips, Geol. Yorkshire, II, 1836, p. 216, pl. 8, fig. 15.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 21.

Loc. Nauvoo, Illinois.

Productus hepar Morton. Upper Carboniferous.

Productus hepar Morton, American Jour. Sci., XXIX, 1836, p. 153, pl. 26, fig. 39.

Loc. Junior Furnace, Scioto County, Ohio.

Obs. Not recognizable.

Productus hildrethanus Norwood and Pratten. Upper Carboniferous.

Productus hildrethianus Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 18, pl. 1, fig. 11.

Loc. Charboniere, Missouri.

Obs. Keyes regards this form as a synonym for P. cora.

Productus hirsutiforme Walcott=Productella hirsutiforme.

Productus hirsutus Hall=Productella hirsuta.

Productus horridus (non Sowerby)=Productus longispina.

Digitized by Google

Productus humboldti d'Orbigny. Upper Carboniferous.

Productus humboldti d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 54, pl. 5, figs. 4–7.—de Koninck, Recherches sur les Animaux Fossiles, Pt. I, 1847, p. 114, pl. 12, fig. 2.—Toula, Sitzb. der k. k. Akad. der Wissensch., XVIII, 1873, p. 16, pl. 2, fig. 3.—Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 695, pl. 76, figs. 1–3.

Productus humboldti ? de Keyserling, Reise in das Petschora-Land, 1846, p. 201, pl. 4, fig. 3.

Loc. Yarbichambi, Bolivia; south end of Spitzbergen; Nishnei-Irginsk, Russia; India; Kashmere.

Productus inca d'Orbigny=Productus semireticulatus.

Producta incurvata Shepard=Strophomena incurvata.

Productus indianaensis Hall. St. Louis (L. Carb.).

Productus indianensis Hall, Trans. Albany Institute, IV, 1858, p. 13.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 47, pl. 6, figs. 6, 7.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 326, pl. 29, figs. 6, 7.

Loc. Spergen Hill, Indiana.

Productus inflatus McChesney. Upper Carboniferous.

Productus inflatus McChesney, New Pal. Fossils, 1860, p. 40;—Trans. Chicago Acad. Sci., I, 1868, p. 27, pl. 6, fig. 1.

Loc. Leavenworth, Indiana.

Productus ivesi Newberry. Upper Carboniferous.

Productus ivesi Newberry, Ives's Rep. Colorado River of the West, 1861, p. 122, pl. 2, figs. 1–8.

Loc. Colorado River near mouth of Diamond River.

Productus koninckianus Geinitz (non de Verneuil)=Productus cora.

Productus lævicosta White. Kinderhook (L. Carb.).

Productus lævicostus White, Jour. Boston Soc. Nat. Hist., VII, 1860, p. 230.—Keyes, Geol. Survey Missouri, V, 1895, p. 41, pl. 38, fig. 1.

Productus lævicostus ? Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 266, pl. 5, figs. 7, 8.

Loc. Burlington, Iowa; Louisiana, Missouri; Oquirrh Mountains, Utah.

Obs. Compare with P. coræformis.

Productus lasallensis Worthen. Upper Carboniferous.

Productus lasallensis Worthen, Geol. Survey Illinois, V, 1873, p. 569, pl. 25, fig. 9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17A, fig. 13.

Loc. Lasalle, Illinois.

Productus latissimus Sowerby. Carboniferous.

Productus latissimus Sowerby, Mineral Conchology, 1822, pl. 330.—Meek, Bull. U. S. Geol. Survey of the Terr., II, 1876, p. 354, pl. 1, fig. 1.

Loc. Europe; Vancouver Island.

Productus leuchtenbergensis de Koninck. Carboniferous.

Productus leuchtenbergensis de Koninck, Recherches sur les Animaux Fossiles, Pt. I, 1847, p. 121, pl. 14, fig. 3.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 19.

Loc. Europe; Masons Landing, Jersey County, Illinois.

Productus longispina Sowerby ? Upper Carboniferous.

? Productus longispinus Sowerby, Mineral Conchology, I, 1814, p. 154, pl. 68, fig. 1.

Productus longispinus Salter, Quart. Jour. Geol. Soc. London, XVII, 1861, p. 64, pl. 4, fig. 2.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 161, pl.

Digitized by Google

Productus longispina Sowerby?—Continued.

6, fig. 7; pl. 8, fig. 6.—Meek and Worthen, Geol. Survey Illinois, V, 1
569, pl. 25, fig. 10.—White, Wheeler's Expl. and Survey west 100th Me
IV, 1875, p. 118, pl. 8, fig. 5.—Meek, King's U. S. Geol. Expl. 40th Par
1877, p. 78, pl. 8, fig. 4.—Hall, Second Ann. Rep. N. Y. State Geol., 1
50, figs. 1-4.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 1
24, figs. 10, 11.—Herrick, Bull. Denison Univ., II, 1887, p. 48, pl. 2, fi
27, 28.—Keyes, Geol. Survey Missouri, V, 1895, p. 45, fig. 4.

Productus flemingi Roemer (non de Koninck), Kreidebildung Texas, 1
89, pl. 11, fig. 8.—Marcou, Geol. North America, 1858, p. 47, pl. 6, fig. 7

Productus splendens Norwood and Pratten, Jour. Acad. Nat. Sci. Philad
III, 1854, p. 11, pl. 1, fig. 5.—Schiel, Pacific R. R. Reports, II, 1855, p.
1, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 19, fig

Productus splendens (?) Meek and Hayden, Proc. Acad. Nat. Sci. Philad
III, 1859, p. 25.—Newberry, Ives's Rep. Colorado River of the West
p. 124.

Productus wabashensis Norwood and Pratten, Jour. Acad. Nat. Sci. Ph
phia, III, 1854, p. 13, pl. 1, fig. 6.

Productus horridus Geinitz, Carbon und Dyas in Nebraska, 1866, p. 55
fig. 7.

Productus orbignyanus Geinitz (?non de Koninck), Ibidem, 1866, p. 56,
figs. 8–11.

Productus (Marginifera) splendens Smith, Proc. American Phil. Soc., 1
1897, p. 29.

Loc. Throughout the Upper Carboniferous of the United States; Bolivia.

Obs. Since considerable uncertainty exists as to Sowerby's species, it
better to adopt P. orbignyanus de Koninck for the above synonym
costatoides is also regarded by Keyes as a synonym for P. longispinus.

Productus longus Meek. Carbonife

Productus sp. undet. Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p
Productus longus Meek, Ibidem, 1877, end of description.
Productus ivesi? Meek, Ibidem, 1877, pl. 7, fig. 6.
Loc. White Pine district, Nevada.

Productus lyelli de Verneuil=Productus cora.

Productus magnicostatus Swallow. Upper Carbonife

Productus magnicostatus Swallow, Trans. St. Louis. Acad. Sci., I, 1860,
Loc. Johnson County, Missouri.
Obs. Keyes regards this species as a synonym for P. semireticulatus.

Productus magnus Meek and Worthen. Keokuk (L. C

Productus magnus Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia
p. 142;—Geol. Survey Illinois, III, 1868, p. 528, pl. 20, fig. 7.—Keyes,
Survey Missouri, V, 1895, p. 41.
Loc. Monroe County, Illinois; St. Genevieve County, Missouri.
Obs. Compare with P. fentonensis.

Productus margaritaceus Phillips. Upper Carbonife

Producta margaritacea Phillips, Geol. Yorkshire, II, 1836, p. 215, pl. 8, fig
Productus margaritaceus Norwood and Pratten, Jour. Acad. Nat. Sci. Phi
phia, III, 1854, p. 6.
Loc. Near Richmond, Missouri.

Productus marginicinctus Prout. St. Louis (L. C

Productus marginicinctus Prout, Trans. St. Louis Acad. Sci., I, 1857, p. 43,
figs. 1-16.—Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 674, pl. 24, fig
Keyes, Geol. Survey Missouri, V, 1895, p. 43.
Loc. St. Louis, Missouri; Milan, Illinois.
Obs. See Productus wortheni Hall.

Digitized by Google

Productus martini Sowerby=Productus semireticulatus.

Productus mesialis Hall. Keokuk (L. Carb.).

Productus mesialis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 636, pl. 19, fig. 2;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 49, figs. 9, 10.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 18, figs. 9, 10.

Loc. Keokuk, Iowa; Nauvoo, Illinois.

Obs. Keyes regards this species as identical with P. burlingtonensis.

Productus mesolobus Phillips. Carboniferous.

Productus mesoloba Phillips, Geol. Yorkshire, II, 1836, p. 215, pl. 7, figs. 12, 13.

Productus mesolobus Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 630.

Loc. Europe; Feilden Isthmus, lat. 82° 43′.

Productus mexicoanus Shumard. Upper Carboniferous.

Productus mexicanus Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 291.—Kayser, Richthofens China, IV, 1883, p. 182, pl. 28, fig. 7.

Productus mexicanus? White, Wheeler's Expl. and Survey west 100th Meridian, IV, 1875, p. 120, pl. 8, fig. 6.

Loc. Guadalupe Mountains, New Mexico; Lincoln County, Nevada; Lo-Ping, China.

Productus morbillianus A. Winchell. Burlington (L. Carb.).

Producta morbilliana A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 113.

Loc. Burlington, Iowa; Sciotoville, Ohio.

Productus multistriatus Meek. Carboniferous.

Productus multistriata Meek, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 309.

Productus multistriatus Meek, Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p. 350, pl. 1, fig. 8;—King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 76, pl. 8, fig. 3.

Loc. Utah and Nevada.

Productus muricatus Norwood and Pratten. Upper Carboniferous.

Productus muricatus Norwood and Pratten (non Phillips), Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 14, pl. 1, fig. 8.—White, Wheeler's Expl. and Survey west 100th Meridian, IV, 1875, p. 120, pl. 8, fig. 4.—Herrick, Bull. Denison Univ., II, 1887, p. 49.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 228.

Loc. Pike County, Illinois; near Richmond, Missouri; Des Moines Valley, Iowa; Flint Ridge, Ohio; Lake County, Colorado; northern New Mexico.

Obs. Since Phillips's P. muricatus is regarded as a synonym for P. costatus, there is no need for another specific name for Norwood and Pratten species.

Productus nanus Meek and Worthen. Upper Carboniferous.

Productus nanus Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 450;—Geol. Survey Illinois, II, 1866, p. 320, pl. 26, fig. 4.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 227.

Loc. Jefferson County, Iowa; northern New Mexico (White).

Productus navicella Hall=Productella navicella.

Productus nebraskaensis Owen. Upper Carboniferous.

Productus nebrascensis Owen, Geol. Rep. Wisconsin, Iowa, and Minnesota, 1852, p. 584, pl. 5, fig. 3.—McChesney, Trans. Chicago Acad. Sci., I, 1868, p. 24, pl. 1, fig. 7.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 165, pl. 2, fig. 2; pl. 4, fig. 6; pl. 5, fig. 11.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 569, pl. 25, fig. 8.—White, Wheeler's Expl. and Survey west 100th Meridian, IV, 1875, p. 116, pl. 8, fig. 3.—Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 65.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 122, pl. 24, figs. 7–9.—Herrick, Bull. Denison Univ., II, 1887, p. 49, pl. 2,

Digitized by Google

Productus nebraskaensis Owen—Continued.

fig. 30.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 19, figs. 5
Keyes, Geol. Survey Missouri, V, 1895, p. 48, pl. 37, fig. 3.

Productus nebrascensis? Herrick, Bull. Denison Univ., III, 1888, p. 31, pl.
24; pl. 3, fig. 23.

Productus rogersi Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphi
ser., III, 1854, p. 9, pl. 1, fig. 3.—Hall, Pacific R. R. Reports, III, 1856, p
pl. 2, figs. 14, 15.—Meek and Hayden, Proc. Acad. Nat. Sci. Philadel
1859, p. 26.—Newberry, Ives's Rep. Colorado River of the West, 186
121.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 50, figs. 17, 18.

Productus asperus McChesney, New Pal. Fossils, 1860, p. 34.—Hall, Second
Rep. N. Y. State Geol., 1883, pl. 50, figs. 5–7.

Productus wilberanus McChesney, New Pal. Fossils, 1860, p. 36;—Trans. Ch
Acad. Sci., I, 1868, p. 26, pl. 1, fig. 8.

Strophalosia horrescens Geinitz (non Murchison Vern. and Keyser.), Carbo
Dyas in Nebraska, 1866, p. 49.

Loc. Bellevue, Missouri; Illinois; Indiana; Ohio; Nebraska; New Me
Nevada; Arizona; Utah.

Obs. Compare with P. norwoodi.

Productus nevadaensis Meek. Upper Carbonifer

Productus nevadensis Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877,
pl. 8, fig. 2.

Loc. White Pine district, Nevada.

Obs. Compare with Productus punctatus (Martin).

Productus newberryi Hall. Waverly (L. Ca

Productus newberryi Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 1
A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 115.—Herrick,
Denison Univ., IV, 1888, p. 20, pl. 10, figs. 24, 25.—Hall and Clarke, Pal.
York, VIII, Pt. I, 1892, pl. 18, figs. 1–3.

Productella newberryi Hall, Second Ann. Rep. N. Y. State Geol., 1883, p
figs. 1–3.

Loc. Medina County and Newark, Ohio.

Productus newberryi annosus Herrick. Waverly (L. Ca

Productus newberryi var. annosus Herrick, Bull. Denison Univ., IV, 1888, p
pl. 3, fig. 17;—Geol. Ohio, VII, 1895, pl. 23, fig. 13.

Loc. Alexandria, Ohio.

Productus nodicostatus Herrick. Waverly (L. Ca

Productus nodocostatus Herrick, Bull. Denison Univ., IV, 1888, p. 23.

Loc. Rushville, Ohio.

Productus nodosus Newberry. Upper Carbonifer

Productus nodosus Newberry, Ives's Rep. Colorado River of the West, 186
124, pl. 1, fig. 7;—Macombes' Rep. Expl. Exped. Santa Fe to the Great
orado River of the West, 1876, p. 140, pl. 3, fig. 3.

Loc. Santa Fe, New Mexico.

Obs. Probably a synonym for Productus cora d'Orbigny.

Productus norwoodi Swallow. Upper Carbonifer

Productus (Strophalosia?) norwoodii Swallow, Trans. St. Louis Acad. Sci
1858, p. 182.

Productus norwoodi Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1
p. 35.

Loc. Cottonwood Valley, Kansas.

Obs. Compare with Productus pustulosus Phillips and P. scabriculus (Marti
Regarded by Keyes as a synonym for P. nebraskaensis.

Digitized by Google

Productus occidentalis Newberry. Upper Carboniferous.

Productus occidentalis Newberry, Ives's Rep. Colorado River of the West, 1861, p. 122, pl. 2, figs. 9, 10.

Loc. Banks of Cascade River near the junction of Great and Little Colorado rivers.

Productus orbignyanus Geinitz (non de Koninck)=Productus longispinus.

Productus ovatus Hall. St. Louis (L. Carb.).

Productus ovatus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 674, pl. 24, fig. 1;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 49, fig. 19.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 18, fig. 19.

Loc. Ottumwa and Keosauqua, Iowa.

Productus papilio Gabb. Upper Carboniferous.

Productus papilio Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., VIII, 1881, p. 302, pl. 42, fig. 12.

Loc. Lake Titicaca, Bolivia.

Productus papulatus Hall=Productella papulata.

Productus parvulus A. Winchell. Kinderhook (L. Carb.).

Producta parvula A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 4.

Loc. Burlington, Iowa.

Productus parvus Meek and Worthen. Kaskaskia (L. Carb.).

Productus parvus Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 450;—Geol. Survey Illinois, II, 1866, p. 297, pl. 23, fig. 4.—White, Wheeler's Expl. and Survey west 100th Merid., IV, 1875, p. 83, pl. 5, fig. 6.

Loc. Chester, Illinois; Mountain Spring, Nevada.

Productus (?) pectinoideus Shepard.

Producta pectenoidea Shepard, American Jour. Sci., XXXIV, 1838, p. 150, fig. 4.

Loc. Vermilionville, Lasalle County, Illinois.

Obs. The geological position of this species may be Trenton or Upper Carboniferous. The illustration is unsatisfactory.

Productus pertenuis Meek. Upper Carboniferous.

Productus cancrini Geinitz (non de Verneuil), Carbon und Dyas in Nebraska, 1866, p. 54, pl. 4, fig. 6.

Productus pertenuis Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 164, pl. 1, fig. 14; pl. 8, fig. 9.

Loc. Nebraska City, Nebraska; Leavenworth, Kansas; Kansas City, Missouri.

Productus peruvianus d'Orbigny. Upper Carboniferous.

Productus peruvianus d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 52, pl. 4, fig. 4.

Loc. Yarbichambi, Bolivia.

Obs. Probably a synonym for Productus semireticulatus.

Productus phillipsi Norwood and Pratten. Carboniferous.

Productus phillipsii Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 8, pl. 1, fig. 2.

Loc. Big Canyon, Humboldt River, Utah.

Productus pileiformis McChesney=Productus cora.

Productus pileolus Shumard. Upper Carboniferous.

Productus pileolus Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 291.

Loc. Guadalupe Mountains, Texas.

Digitized by Google

Productus pocillum Morton. Upper Carbonif

Productus pocillum Morton, Amer. Jour. Sci., XXIX, 1836, p. 150, pl. 2, fi

Loc. Putnam Hill, Ohio.

Obs. Not recognizable.

Productus popei Shumard. Upper Carbonif

Productus popei Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 290, fig. 8.

Loc. New Mexico and Texas.

Productus portlockianus Norwood and Pratten=Productus cos

Productus prattenianus Norwood=Productus cora.

Productus punctatus (Martin). Upper Carbonif

Anomites punctatus Martin, Petrefacta Derbiensia, 1809, p. 8, pl. 37, fig.

Productus punctatus? Morton, American Jour. Sci., XXIX, 1836, p. 153, fig. 38.

Productus punctatus Shumard, Marcy's Rep. U. S. Expl. Red River, Lou 1853, p. 201, pl. 1, fig. 5; pl. 2, fig. 1.—Norwood and Pratten, Jour. Nat. Sci. Philadelphia, III, 1854, p. 19.—Marcou, Geol. North Americ p. 48, pl. 6, fig. 12.—Geinitz, Carbon und Dyas in Nebraska, 1866, McChesney, Trans. Chicago Acad. Sci., I, 1868, p. 27, pl. 1, figs. 10, 11.— Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 169, pl. 2, fig. 6; pl 5.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 569, pl. 25, fi White, Wheeler's Expl. and Survey west 100th Meridian, IV, 1875, p. 7, fig. 2;—Eleventh Rep. State Geol. Indiana, 1882, p. 373, pl. 42, figs Hall, Second Ann. Rep. N. Y. State Geol. 1883, pl. 50, figs. 14–16.— Thirteenth Rep. State Geol. Indiana, 1884, p. 124, pl. 27, figs. 1–3.—H Bull. Denison Univ., II, 1887, p. 48, pl. 2, fig. 29.—Hall and Clarke, P York, VIII, Pt. I, 1892, pl. 17A, fig. 21; pl. 19, figs. 14–18.—Keyes Survey Missouri, V, 1895, p. 51, pl. 37, fig. 1.—Smith, Proc. America Soc., XXXV, 1897, p. 29 (extract).

Productus semipunctatus Sheppard, American Jour. Sci., XXXIV, 1838, fig. 9.

Productus tubulospinus McChesney, New Pal. Fossils, 1860, p. 37.

Productus allied to punctatus Etheridge, Quart. Jour. Geol. Soc. L XXXIV, 1878, p. 630.

Loc. Europe; Ohio; Indiana; Illinois; Missouri; Arkansas; Nebraska; Nevada; New Mexico; Feilden Isthmus, lat. 82° 43′.

Productus pustulosus Phillips. Upper Carbonif

Producta pustulosa Phillips, Geol. Yorkshire, II, 1836, p. 216, pl. 7, fig. 1

Productus pustulosus Marcou, Geol. North America, 1858, p. 48, pl. 6, f Geinitz, Carbon und Dyas in Nebraska, 1866, p. 55.

Productus pyxidiformis Marcou, Geol. North America, 1858, p. 48, pl. 6, f

Productus pustulosus? Meek and Hayden, Proc. Acad. Nat. Sci. Philad 1859, p. 26.

Loc. Europe; Leavenworth, Kansas; Tigeras, New Mexico.

Obs. See Productus norwoodi.

Productus pyxidatus Hall=Productella pyxidata.

Productus pyxidiformis de Koninck=Productus pustulosus.

Productus raricostatus Herrick. Waverly (L. C

Productus raricostatus Herrick, Bull. Denison Univ., IV, 1888, p. 19, pl. 19;—Geol. Ohio, VII, 1895, pl. 22, fig. 9.

Loc. Moots Run, Ohio.

Productus rarispinus Hall=Productella rarispina.

Digitized by Google

Productus reticulatus Gabb. Upper Carboniferous.

Productus reticulatus Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., VIII, 1881, p. 302, pl. 42, fig. 13.

Loc. Lake Titicaca, Bolivia.

Productus rhomianus Derby. Upper Carboniferous.

Productus rhomianus Derby, Bull. Cornell Univ., I, 1874, p. 56, pl. 3, figs. 20, 41–44, 49.

Loc. Bomjardim and Itaituba, Brazil.

Productus rogersi Norwood and Pratten=Productus nebraskaensis.

Productus rushvillensis Herrick. Waverly (L. Carb.).

Productus rushvillensis Herrick, Bull. Denison Univ., IV, 1888, p. 22, pl. 3, fig. 15;—Geol. Ohio, VII, 1895, pl. 23, fig. 15.

Loc. Rushville, Newark, and Londonville, Ohio.

Productus scabriculus (Martin). Lower and Upper Carboniferous.

Anomites scabriculus Martin, Petrefacta Derbiensia, 1809, p. 8, pl. 36, fig. 5.

Productus scabriculus Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 17.—Marcou, Geol. North America, 1858, p. 47, pl. 5, fig. 6.—Newberry, Ives's Rep. Colorado River of the West, 1861, p. 125.

Productus scabriculus? Geinitz, Carbon und Dyas in Nebraska, 1866, p. 54.

Loc. Europe; Pecos Village and Santa Fe, New Mexico; Plattsmouth, Nebraska; Caldwell County, Kentucky; Kashmere.

Productus scitulus Meek and Worthen. St. Louis (L. Carb.).

Productus scitulus Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 451;—Geol. Survey Illinois, II, 1866, p. 280, pl. 20, fig. 5.

Loc. Alton, Illinois.

Productus semipunctatus Sheppard=Productus punctatus.

Productus semireticulatus Hall, 1852 (non Martin)=Productus cora.

Productus semireticulatus (Martin). Lower and Upper Carboniferous.

Anomites semireticulatus Martin, Petrefacta Derbiensia, 1809, p. 7, pl. 32, figs. 1, 2; pl. 33, fig. 4.

Productus inca d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 51, pl. 4, figs. 1–3.—Derby, Bull. Mus. Comp. Zool., III, 1876, p. 280.

Productus semireticulatus Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 11.—Hall, Pacific R. R. Reports, III, 1856, p. 103, pl. 2, figs. 16, 17;—Geol. Survey Iowa, I, Pt. II, 1858, p. 637.—Marcou, Geol. North America, 1858, p. 46, pl. 5, fig. 4; pl. 6, fig. 6.—Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 292.—Newberry, Ives's Rep. Colorado River of the West, 1861, p. 124.—Salter, Quart. Jour. Geol. Soc. London, XVII, 1861, p. 64, pl. 4, fig. 1.—Davidson, Ibidem, XIX, 1863, p. 174, pl. 9, figs. 20, 21.—Meek, Pal. California, I, 1864, p. 11, pl. 2, fig. 4.—Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 115.—Geinitz, Carbon und Dyas in Nebraska, 1866, p. 51.—Toula, Sitzb. der k. k. Akad. der Wissensch. zu Wien, IX, 1869, p. 9.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 160, pl. 5, fig. 7.—Derby, Bull. Cornell Univ., I, 1874, p. 47, pl. 4, fig. 8; pl. 6, fig. 18; pl. 7, figs. 5–7, 15, 16.—White, Wheeler's Expl. and Survey west of the 100th Meridian, IV, 1875, p. 111, pl. 8, fig. 1.—Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 69, pl. 7, fig. 5.—Hall and Whitfield, Ibidem, 1867, p. 267, pl. 5, figs. 5, 6.—Dawson, Acadian Geol., 3d ed., 1878, p. 296, fig. 97.—Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 629.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 49, figs. 11–13; pl. 50, figs. 19–23.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 125, pl. 24, figs. 1–3.—Herrick, Bull. Denison Univ., III, 1888, p. 31, pl. 1, fig. 26; pl. 3, fig. 24; pl. 7, fig. 11; pl. 10,

Digitized by Google

Productus semireticulatus (Martin)—Continued.

fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17A, figs.
pl. 18, figs. 11-13; pl. 19, figs. 19-23.—Keyes, Geol. Survey Missouri, V
p. 50, pl. 36, fig. 4.

Productus calhounianus Swallow, Trans. St. Louis Acad. Sci., I, 1858, p
215.—Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p
Newberry, Ives's Rep. Colorado River of the West, 1861, p. 123.

Productus setigerus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 638, pl. 19,

Productus setigerus var. keokuk Hall, Geol. Survey Iowa, I, Pt. II, 1858,
pl. 19, fig. 4.

Productus martini A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863,

Productus magnus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p
fig. 15.

Loc. Europe; throughout the Carboniferous of North America; Feilden Is
lat. 82° 43′; Vixixil and Sansignan, Guatemala; Yarbichambi, Bolivia;
jardim and Itaituba, Brazil; Tibet and Kashmere.

Obs. See Productus peruvianus d'Orbigny and P. magnicostatus.

Productus semireticulatus kansasensis Swallow. Upper Carbonife

Productus calhounianus var. kansasensis Swallow, Trans. St. Louis Acad
I, 1858, p. 216.

Loc. Kansas and Missouri.

Productus semistriatus Meek. Upper Carbonife

Productus semistriatus Meek, Proc. Acad. Nat. Sci. Philadelphia, 1860, p.
Meek, Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p. 349, pl.
7;—King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 74, pl. 7, fig. 8.—
Wheeler's Expl. and Survey west 100th Meridian, 1881, Appendix, p.

Loc. Utah and northern New Mexico.

Productus setigerus Hall=Productus semireticulatus.

Productus setigerus var. keokuk Hall=Productus semireticulatus

Productus shumardianus Hall=Productella shumardana.

Productus speciosus Hall=Productella speciosa.

Productus spinulicostus Hall=Productella spinulicosta.

Productus splendens Norwood and Pratten=Productus longispin

Productus subaculeatus of American authors=Productella spinulic

Productus subalatus Hall=Productella subalata.

Productus subhorridus Meek. Carbonife

Productus subhorridus Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877,
pl. 7, fig. 3.

Loc. Wasatch Mountains, Utah.

Productus sulcatus Castelnau=Leptæna rhomboidalis.

Productus sulcifer de Verneuil=Leptæna rhomboidalis.

Productus swallovi Beecher. Kaskaskia (L. Ca

Koninckina americana Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 9
Productus swallovi Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 214.

Loc. Barretts Station, St. Louis County, Missouri.

Productus symmetricus McChesney. Upper Carbonife

Productus symmetricus McChesney, New Pal. Fossils, 1860, p. 35;—Trans
cago Acad. Sci., I, 1868, p. 25, pl. 1, fig. 9.—Meek, Final Rep. U. S.
Survey of Nebraska, 1872, p. 167, pl. 5, fig. 6; pl. 8, fig. 13.—White,
teenth Rep. State Geol. Indiana, 1884, p. 123, pl. 25, figs. 1 and 2.—Hal

Digitized by Google

Productus symmetricus McChesney—Continued.

Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17A, figs. 19, 20.—Keyes, Geol. Survey Missouri, V, 1895, p. 48, pl. 36, fig. 2.

Loc. Lasalle and Springfield, Illinois; Iowa; Missouri; Nebraska; Indiana.

Productus tenuicostatus Hall. St. Louis (L. Carb.).

Productus tenuicostatus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 675, pl. 24, fig. 2;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 49, fig. 18.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 18, fig. 18.—Keyes, Geol. Survey Missouri, V, 1895, p. 44.

Loc. Milan, Illinois.

Productus truncatus Hall=Strophalosia truncata.

Productus tubulospinus Sheppard=Productus punctatus.

Productus undiferus de Koninck. Upper Carboniferous.

Productus undiferus de Koninck, Mém. de la Soc. Royale des Sciences de Liége, IV, 1846, p. 153, pl. 5, fig. 4; pl. 11, fig. 5.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 9.

Loc. Europe; Caseyville, Illinois; Posey County, Indiana.

Obs. See Productus boonensis Swallow.

Productus villiersi d'Orbigny. Upper Carboniferous.

Productus villiersi d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 53, pl. 4, figs. 12, 13.—de Koninck, Recherches sur les Animaux Fossiles, Pt. I, 1847, p. 109, pl. 11, fig. 1.—Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 17.

Loc. Yarbichambi, Bolivia; Keg Creek, Missouri.

Productus viminalis White. Burlington (L. Carb.).

Productus viminalis White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 29.

Loc. Burlington, Iowa.

Obs. White regards this species as a synonym for Productus costatus Sowerby.

Productus vittatus Hall=Productus alternatus.

Productus wabashensis Norwood and Pratten=Productus longispina.

Productus wallacianus Derby. Upper Carboniferous.

Productus wallacianus Derby, Bull. Cornell Univ., I, 1874, p. 57, pl. 3, figs. 46–48; pl. 6, fig. 5.

Loc. Bomjardim and Itaituba, Brazil.

Productus wilberanus McChesney=Productus nebraskaensis.

Productus wortheni Hall. Keokuk (L. Carb.).

Productus wortheni Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 635, pl. 19, fig. 1.

Loc. Nauvoo, Illinois.

Obs. Compare with Productus marginicinctus Prout.

Productus weyprechti Toula. Upper Carboniferous.

Productus weyprechti Toula, Sitzb. der k. k. Akad. der Wissensch. zu Wien, 1873, p. 138, pl. 1, fig. 4.

Productus weyprechti? Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 631.

Loc. Cape Joseph Henry, lat. 82° 50′.

PROTORHYNCHA Hall and Clarke. Genotype Atrypa dubia Hall.

Protorhyncha Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 180;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 824.

Digitized by Google

Protorhyncha (?) antiquata (Billings). Lower Cam

Camarella antiquata Billings, Pal. Fossils, I, 1861, p. 10, fig. 13;—Geol. V
II, 1861, p. 949, fig. 353;—Geol. Canada, 1863, p. 284, fig. 290.—Walcot
U. S. Geol. Survey, 30, 1886, p. 122, pl. 7, fig. 8;—Tenth Ann. Rep. U.
Survey, 1891, p. 613, pl. 72, fig. 3.

Camarella ? antiquata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893

Loc. Swanton, Vermont.

Protorhyncha dubia Hall. Chazy

Atrypa dubia Hall, Pal. New York, I, 1847, p. 21, pl. 4 bis, fig. 5.

Rhynchonella dubia Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 185

Protorhyncha dubia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893,

Loc. Chazy, New York; Highbridge, Kentucky; Lascassas, Tennessee.

Protorhyncha (?) minor (Walcott). Lower Cam

Camarella (?) minor Walcott, Proc. U. S. Nat. Mus., XII, 1889, p. 36;-
Ann. Rep. U. S. Geol. Survey, 1891, p. 614, pl. 72, fig. 4.—Hall and
Pal. New York, VIII, Pt. II, 1893, p. 221.

Loc. Stissingville, New York.

Obs. May be the type of a new genus. Its affinities are rather with the
chonellidæ than with Pentameridæ.

Protorthis Hall and Clarke=Billingsella.

Protosiphon Matthew. Genotype P. kempanus Ma

Protosiphon Matthew, Geol. Mag., dec. IV, IV, 1897, p. 70.

Protosiphon kempanus Matthew. Lower Cam

Protosiphon kempanum Matthew, Geol. Mag., dec. IV, IV, 1897, p. 70, fi

Loc. Long Island, Kings County, New Brunswick.

Protozyga Hall and Clarke=Zygospira.

Pseudocrania anomala A. Winchell=Orthothetes anomalus.

PTYCHOSPIRA Hall and C. Genotype Terebratula ferita von

Ptychospira Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 112, fig
Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 792.

Ptychospira sexplicata (White and Whitfield.) Waverly (L. C

Retzia sexplicata White and Whitfield, Proc. Boston Soc. Nat. Hist., VII
p. 294.

Ptychospira sexplicata Hall and Clarke, Pal. New York, VIII, Pt. II, 1
112, pl. 50, figs. 13, 14; pl. 83, fig. 28.

Loc. Burlington, Iowa.

PUGNAX Hall and C. Genotype Rhynchonella acuminata (Ma

Pugnax Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 202;—Thi
Ann. Rep. N. Y. State Geologist, 1895, p. 828.

Obs. Subgenus of Hypothyris.

Pugnax (?) dawsoniana (Davidson). Upper Carbonif

Rhynchonella dawsoniana Davidson, Quart. Jour. Geol. Soc. London, XI
p. 172, pl. 9, figs. 13, 14.

Rhynchonella ? dawsoniana Dawson, Acadian Geology, 3d ed., 1878,
fig. 93.

Pugnax (?) dawsonianus Hall and Clarke, Pal. New York, VIII, Pt. II, 1
214, pl. 62, figs. 30–33.

Loc. Lennox Passage, Nova Scotia.

Digitized by Google

Pugnax globulina (Phillips sp.?) (Davidson). Upper Carboniferous.

? Terebratula globulina Phillips, Encyl. Metr., IV, 1834, pl. 3, fig. 3.

Camarophoria? globulina? Davidson, Quart. Jour. Geol. Soc. London, XIX, 1863, p. 171, pl. 9, figs. 11, 12.

Camarophoria globulina? Dawson, Acadian Geology, 3d ed., 1878, p. 293, fig. 92.

Pugnax globulina Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 214.

Loc. De Bert River, Nova Scotia.

Pugnax grosvenori Hall. St. Louis (L. Carb.).

Rhynchonella grosvenori Hall, Trans. Albany Institute, IV, 1858, p. 10.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 53, pl. 6, figs. 31–34.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 331, pl. 29, figs. 31–34.

Pugnax grosvenori Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 60, figs. 13–17.

Loc. Spergen Hill and Bloomington, Indiana; Alton, Illinois; near Princeton, Kentucky.

Pugnax mutata Hall. Keokuk and St. Louis (L. Carb.).

Rhynchonella mutata Hall, Trans. Albany Institute, IV, 1858, p. 10;—Geol. Survey Iowa, I, Pt. II, 1858, p. 658, pl. 23, fig. 2.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 52, pl. 6, fig. 46.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 332, pl. 29, figs. 43–45.

Pugnax mutatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 204, pl. 60, figs. 18–22.

Loc. Alton and Warsaw, Illinois; Boonville, Missouri.

Pugnax ottumwa (White). St. Louis (L. Carb.).

Rhynchonella ottumwa White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 23;—Twelfth Ann. Rep. U. S. Geol. Survey Terr., 1883, p. 165, pl. 41, fig. 5.

Pugnax ottumwa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 204, pl. 60, figs. 23–26.

Loc. Ottumwa and Oskaloosa, Iowa; Clark County, Missouri.

Pugnax pugnus (Martin). Upper Devonian.

Conchyliolithus Anomites pugnus Martin, Petrefacta Derbiensia, 1809, tab. 22, figs. 4, 5.

Terebratula pugnus Sowerby, Mineral Conchology, 1825, pl. 425, figs. 1–6.

Rhynchonella pugnus Davidson, Mon. British Carb. Brach., Pal. Soc., 1860, p. 97, pl. 32, figs. 1–15.—Williams, American Jour. Sci., 3d ser., XXV, 1883, p. 99.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 155, pl. 14, fig. 7.—Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 73.—Whiteaves, Cont. Canadian Pal., I, 1891, pp. 230, 290.

? Rhynchonella pugnus Dawson, Acadian Geology, 3d ed., 1878, p. 295.

Pugnax pugnus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 203, pl. 60, figs. 6–10.

Loc. Europe; High Point, New York; Eureka district, Nevada; Mackenzie and Athabasca rivers, Canada; in the Carboniferous of Windsor and East River, Nova Scotia (Dawson); San Saba Valley, Texas (Roemer).

Pugnax pugnus alta (Calvin). Upper Devonian.

Rhynchonella alta Calvin; paper read before the Iowa Acad. Sci., and a named photographic plate distributed.

Rhynchonella pugnus var. alta Williams, Bull. Geol. Soc. America, I, 1890, pl. 12, figs. 5–7.

Pugnax altus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 203, pl. 60, figs. 1–5.

Loc. Solon, Iowa.

Digitized by Google

Pugnax pugnus missouriensis (Shumard). Waverly (L. C

Rhynchonella missouriensis Shumard, Geol. Rep. Missouri, 1855, p. 204, fig. 5a (non figs. 5b, 5c = Pugnax striaticostata).—Meek and Worthen Survey Illinois, II, 1866, p. 153, pl. 14, fig. 4.—Keyes, Geol. Survey Mi V, 1895, p. 100.

Pugnax missouriensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pl. 60, figs. 33, 34; pl. 62, figs. 44, 45.

Loc. Cooper County, Missouri; Burlington, Iowa; Rockford, Indiana; ville and Richfield, Ohio.

Pugnax rockymontana (Marcou). Upper Carbonif

Terebratula rockymontana Marcou, Geol. N. America, 1858, p. 50, pl. 6, fi

Rhynchonella eatoniæformis McChesney, New Pal. Fossils, 1860, p. 49.

Rhynchonella rockymontana White, Wheeler's Expl. and Survey west Merid., IV, 1875, p. 131, pl. 9, fig. 1.

Pugnax eatoniiformis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pl. 60, figs. 11, 12.

Loc. Pecos Village, New Mexico; Cedar Range, Utah; Graysville, Illinois

Pugnax striaticostata (Meek and Worthen). Kinderhook (L. C

Rhynchonella missouriensis Shumard, Geol. Rep. Missouri, 1855, p. 204, figs. 5b, 5c (non 5a = Pugnax pugnus missouriensis).—Meek and We Geol. Survey Illinois, III, 1868, p. 450, pl. 14, fig. 7.

Rhynchonella striatocostata Meek and Worthen, Ibidem, III, 1868, p. 452

Pugnax striatocostata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893,

Loc. Cooper County, Missouri.

Pugnax swallovana (Shumard). Upper Carbonif

Camarophoria swallovana Shumard, Trans. St. Louis Acad. Sci., I, 1859, pl. 11, fig. 1.

Pugnax swalloviana Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 60, figs. 27–32.

Loc. Guadalupe Mountains of New Mexico and Texas.

Pugnax utah (Marcou). Upper Carbonif

Terebratula utah Marcou, Geol. N. America, February, 1858, p. 51, pl. 6,

Rhynchonella (Camarophoria) osagensis Swallow, Trans. St. Louis Acad. June, 1858, p. 219.

Rhynchonella utah, Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia p. 27.—Newberry, Ives's Rep. Colorado River of the West, 1861, p. White, Wheeler's Expl. and Survey west 100th Meridian, IV, 1875, p. 1 9, fig. 2;—Thirteenth Rep. State Geol. Indiana, 1884, p. 132, pl. 25, fig

†Rhynchonella species Salter, Quart. Jour. Geol. Soc. London, XVII, 1861 pl. 4, fig. 5.

Camarophoria globulina Geinitz (non Phillips), Carbon und Dyas in Neb 1866, p. 38, pl. 3, fig. 5.

Rhynchonella osagensis Meek, Final Rep. U. S. Geol. Survey Nebraska, 18 179, pl. 1, fig. 9; pl. 6, fig. 2.—Meek and Worthen, Geol. Survey Illin 1873, p. 571, pl. 26, fig. 22.

Pugnax utah Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 204, figs. 39–42.

Rhynchonella uta Keyes, Geol. Survey Missouri, V, 1895, p. 103, pl. 41, fig.

Loc. Salt Lake City, Utah; Indiana; Illinois; Iowa; Missouri; Kansas; Arka Nebraska.

Obs. Compare with Pugnax pleurodon.

Digitized by Google

C. Genotype Strophomena alternata Emmons.

sque) Billings, Canadian Nat. Geol., I, 1856, p. 133;—
1861, p. 329;—Pal. Fossils, I, 1862, p. 115.—Hall, Pal.
. 76.—Meek, Pal. Ohio, I, 1873, p. 73.—N. H. Winchell,
l. Nat. Hist. Survey Minnesota, 1881, p. 118.—Shaler,
f the Ohio Valley, 1887, p. 4.—Herrick, Bull. Denison
p. 14.—Nettelroth, Kentucky Fossil Shells, Mem. Ken-
889, p. 159.

arke, Pal. New York, VIII, Pt. I, 1892, p. 281.—Winchell
sota Geol. Survey, III, 1893, p. 400.—Hall and Clarke,
. Y. State Geologist, 1894, p. 279.

nmons). Trenton to Lorraine (Ord.).

d, Second Ann. Rep. N. Y. Geol. Survey, 1838, p. 115
al. New York, I, 1847, pp. 102, 286, pl. 31, fig. 1; pl. 31A,
-Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 818,

onrad, Third Ann. Rep. N. Y. Geol. Survey, 1839, p. 63
Rep. Ibidem, 1840, p. 201 (undefined);—Fifth Rep.
ndefined).—Emmons, Geol. N. Y.; Rep. Second Dist.,
illings, Canadian Nat. Geol., I, 1856, p. 204, figs. 3, 4;—
V, 1860, p. 51;—Pal. Fossils, I, 1862, p. 117;—Geol.
ig. 140.—Meek, Pal. Ohio, I, 1873, p. 88, pl. 7, fig. 1.—
rt. Jour. Sci., II, 1875, p. 51.—White, Second Ann. Rep.
atistics and Geol., 1880, p. 481, pl. 1, figs. 6, 7;—Tenth
iana, 1881, p. 113, pl. 1, figs. 6, 7.—Hall, Second Ann.
l., 1883, pl. 38, figs. 6–11.—Shaler, Fossil Brachiopoda
887, p. 4, pls. 2, 3.—Keyes, Geol. Survey Missouri, V,
3.

nau, Essai Système Silurien l'Amérique Septentrionale,
6.

on Pander), Ibidem, 1843, p. 38, pl. 14, fig. 1.
Owen, Geol. Expl. Iowa, Wisconsin, and Illinois, 1844,

is Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 62.
all and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 282,
; Pt. II, 1895, pl. 84, figs. 17, 18.—Winchell and Schu-
Survey, III, 1893, p. 404, pl. 31, figs. 32–34.—Whiteaves,
I, 1897, p. 171.

diana; Illinois; Missouri; Wisconsin; Minnesota; Can-
costi.

defined or figured by Conrad. The first illustration
s, and in the following year it was figured and defined
is huroniensis.

rnistriata Hall. Lorraine (Ord.).

all, Pal. New York, I, 1847, p. 109, pl. 31B, fig. 1.
a Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859,

ar. alternistriata Miller, Cincinnati Quart. Jour. Sci.,

a Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p.

aysville, Kentucky; Madison, Indiana.
variety as a synonym for S. alternata.

Digitized by Google

Rafinesquina alternata fracta (Meek). Lorraine (

Strophomena alternata var. fracta Meek, Pal. Ohio, I, 1873, p. 91, pl. 7, fig
Strophomena fracta Miller, Cincinnati Quart. Jour. Sci., I, 1874, p. 13;—I
II, 1875, p. 54.
Loc. Cincinnati, Ohio.

Rafinesquina alternata loxorhytis Winchell and Schuchert=R.

Rafinesquina alternata loxorhytis (Meek). Lorraine (

Strophomena alternata var. loxorhytis Meek, Pal. Ohio, I, 1873, p. 91.—
Cincinnati Quart. Jour. Sci., II, 1875, p. 53.
Loc. Cincinnati, Ohio.

Rafinesquina alternata nasuta (Conrad). Lorraine (

Strophomena nasuta Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1
260.—Emmons, Geol. New York; Rep. Third Dist., 1842, p. 403, fig. 3.
Strophomena alternata var. nasuta Miller, Cincinnati Quart. Jour. Sc
1875, p. 53.
Loc. Jefferson County, New York; Cincinnati, Ohio.

Rafinesquina (?) atava (Matthew). Calciferous (

Strophomena atava Matthew, Trans. Royal Soc. Canada, 1893, p. 102, pl. 7,
Loc. Mary Island, near St. John, New Brunswick.

Rafinesquina aurora (Billings). Calciferous (

Strophomena aurora Billings, Pal. Fossils, I, 1865, p. 218, fig. 202.
Loc. Table Head, etc., Newfoundland.

Rafinesquina ceres (Billings). Lorraine and Anticosti (Ord. and

Strophomena ceres Billings, Canadian Nat. Geol., V, 1860, p. 54;—Pal. F
I, 1862, p. 119.
Loc. Anticosti.

Rafinesquina deltoidea (Conrad). Trenton and Utica (

Strophomena deltoidea Conrad, Third Ann. Rep. N. Y. Geol. Survey, 1
64;—Fifth Rep., Ibidem, 1841, p. 37.—Vanuxem, Geol. N. Y.; Rep.
Dist., 1842, p. 46, fig. 2.—Emmons, Geol. N. Y.; Rep. Second Dist., 1
389, fig. 2.—Billings, Geol. Canada, 1863, p. 163, fig. 141.—Keyes, Geol
vey Missouri, V, 1895, p. 69.
Strophomena camerata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII,
p. 254, pl. 14, fig. 5.
Leptæna camerata Hall, Pal. New York, I, 1847, p. 106, pl. 31A, fig. 2.
Leptæna deltoidea Hall, Ibidem, 1847, p. 106, pl. 31A, fig. 3.
Streptorhynchus (Strophonella) deltoidea Hall, Second Ann. Rep. New
State Geol., 1883, pl. 42, figs. 1, 2, 4 (non fig. 3).
Refinesquina deltoidea Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p
figs. 1, 2, 4.—Winchell and Schuchert, Minnesota Geol. Survey, III, 18
403, pl. 31, figs. 30, 31.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 170.
Loc. Trenton Falls, etc., New York; St. Paul, Cannon Falls, etc., Minn
Oshkosh, Wisconsin; Dubuque, Iowa; Pike County, Missouri; Ottaw
Lake Winnipeg, Canada.

Rafinesquina fasciata Hall. Chazy (

Leptæna fasciata Hall, Pal. New York, I, 1847, p. 20, pl. 4 bis, fig. 3.
Strophomena fasciata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859,
Rafinesquina fasciata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p
Loc. Chazy, Clinton County, New York.
Obs. Should be compared with R. alternata.

Rafinesquina imbrex (Pander). Lorraine (

Strophomena imbrex(?) Billings, Pal. Fossils, I, 1862, p. 128, fig. 106.
Loc. Europe; Anticosti.

Digitized by Google

Rafinesquina incrassata (Hall). Chazy and Black River (Ord.).

Leptæna incrassata Hall, Pal. New York, I, 1847, p. 19, pl. 4 bis, fig. 2.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 817, fig. 591.

Strophomena incrassata Billings, Canadian Nat. Geol., IV, 1859, p. 443.

Loc. Chazy, New York; Mingan Island, Canada.

Rafinesquina kingi (Whitfield). Lorraine (Ord.).

Strophomena kingi Whitfield, Ann. Rep. Geol. Survey Wisconsin, 1877, p. 72;—Geol. Wisconsin, IV, 1882, p. 261, pl. 12, figs. 15, 16.

Rafinesquina alternata var. loxorhytis Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 407, pl. 31, figs. 35-37; pl. 32, figs. 59, 60.

Rafinesquina kingi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 283.

Loc. Delafield, Wisconsin; near Spring Valley, Minnesota.

Rafinesquina lata Whiteaves. Lorraine (Ord.).

Rafinesquina lata Whiteaves, Canadian Rec. Sci., 1895, p. 392;—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 172, pl. 19, figs. 2–5.

Loc. Red River Valley and Lake Winnipeg, Manitoba.

Rafinesquina mesicosta (Shumard). ? Trenton (Ord.).

Leptæna mesacosta Shumard, Geol. Rep. Missouri, 1855, p. 205, Pl. C, fig. 2.—Keyes, Geol. Survey Missouri, V, 1895, p. 76.

Loc. Cape Girardeau, Missouri.

Rafinesquina minnesotaensis (N. H. Winchell). Trenton (Ord.).

Strophomena deltoidea Owen (non Conrad), Geol. Expl. Iowa, Wisconsin, and Illinois, 1844, pl. 16, fig. 8; pl. 17, fig. 6.

Leptæna deltoidea Owen, Geol. Rep. Wisconsin, Iowa, and Minnesota, 1852, p. 620, tab. 2B, fig. 10 (not the middle figure).

Strophomena incrassata Hall (non 1847), Geol. Wisconsin, I, 1862, p. 42, fig. 16.—Hall (non 1847), Second Ann. Rep. N. Y. State Geol., 1883, pl. 38, figs. 1–5.

Strophomena minnesotensis N. H. Winchell, Ninth Ann. Rep. Geol. Nat. Hist. Survey Minnesota, 1881, p. 120.

Rafinesquina minnesotensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 283.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 401, pl. 31, figs. 25–29.

Loc. Minneapolis, etc., Minnesota; Beloit, Wisconsin; Decorah and McGregor, Iowa; central Kentucky; Lebanon, Tennessee.

Obs. This species is probably not identical with R. incrassata (Hall) of the Chazy terrane.

Rafinesquina minnesotaensis inquassa (Sardeson). Trenton (Ord.).

Strophomena inquassa Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 334, pl. 5, figs. 22–24.

Rafinesquina minnesotensis var. inquassa Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 403, pl. 31, figs. 27, 28.

Loc. Minneapolis and St. Paul, Minnesota; Mineralpoint, Wisconsin.

Rafinesquina nitens (Billings). Lorraine (Ord.).

Strophomena nitens Billings, Canadian Nat. Geol., V, 1860, p. 53, fig. 1;—Pal. Fossils, I, 1862, p. 118, fig. 97;—Geol. Canada, 1863, p. 209, fig. 208.

Rafinesquina nitens Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 283.

Loc. Anticosti.

Rafinesquina (?) obscura Hall. Clinton (Sil.).

Leptæna obscura Hall, Pal. New York, II, 1852, pp. 62, 103, pl. 21, figs. 2, 6.

Strophomena obscura Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.

Strophomena obscura? Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 306, pl. 6, figs. 15, 16.

Rafinesquina ? obscura Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 283.

Loc. Near Utica and Kirkland, New York; Cumberland Gap, Tennessee.

Digitized by Google

Rafinesquina squamula (James). Lorraine (

Strophomena squamula James, Cincinnati Quart. Jour Sci., I, 1874, p. 33
Rafinesquina squamula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,
Loc. Cincinnati, Ohio.

Rafinesquina tenuilineata (Conrad). Trenton (

Strophomena tenuilineata Conrad, Jour. Acad. Nat. Sci. Philadelphia 1842, p. 259.—Hall, Twelfth Rep. New York State Cab. Nat. Hist., 185
Leptæna tenuilineata Hall, Pal. New York, I, 1847, p. 115, pl. 31B, fig. 8.
Loc. "Occurs in Trenton limestone."

Rafinesquina ulrichi (James). Utica (

Strophomena (?) ulrichi James, The Palæontologist, 1, 1878, p. 6.
Rafinesquina ulrichi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 15A, figs. 37, 38.
Loc. Cincinnati, Ohio.

RENSSELÆRIA Hall. Genotype Terebratula ovoides

Rensselæria Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 39 New York, III, 1859, p. 454.—Dall, American Jour. Conchology, VI, 105.—Claypole, Proc. American Philosophical Soc., 1883, p. 235.—H Clarke, Pal. New York, VIII, Pt. II, 1893, p. 255;—Thirteenth An N. Y. State Geologist, 1895, p. 849.

Rensselæria æquiradiata (Conrad). Lower Helderberg (

Atrypa æquiradiata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1 266, pl. 16, fig. 17.
Meganteris æquiradiata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 185 figs. 1-3.
Rensselæria æquiradiata Hall, Pal. New York, III, 1859, p. 255, pl. 45, f Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 258, pl. 76, figs
Loc. Cherry Valley, Schoharie, and Carlisle, New York; Arisaig, Nova (Ami).

Rensselæria cayuga Hall and Clarke. Oriskany (

Rensselæria cayuga Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p 370, pl. 75, figs. 1, 2.
Loc. Cayuga, Ontario.

Rensselæria condoni McChesney=Megalanteris condoni.

Rensselæria cumberlandiæ Hall. Oriskany (

Meganteris cumberlandiæ Hall, Tenth Rep. N. Y. State Cab. Nat. Hist. p. 101.
Rensselæria cumberlandiæ Hall, Pal. New York, III, 1859, p. 464, pl. 108, f Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 258, pl. 77, figs.
Loc. Cumberland, Maryland.

Rensselæria elliptica Hall. Lower Helderberg (

Meganteris elliptica Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p
Rensselæria elliptica Hall, Pal. New York, III, 1859, p. 256, pl. 45, fig. 4. and Clarke, Ibidem, VIII, Pt. II, 1893, p. 258, pl. 76, figs. 26-28.
Loc. Schoharie County, New York.

Rensselæria elongata Hall=Amphigenia elongata.

Rensselæria intermedia Hall. Oriskany (

Rensselæria intermedia Hall, Pal. New York, III, 1859, p. 463, pl. 108, fig Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 77, figs. 26-28.
Loc. Cumberland, Maryland.

Rensselæria johanni Hall=Newberrya johannis.

Digitized by Google

Rensselæria lævis Hall=Meristella lævis.

Rensselæria lævis Meek=Newberrya lævis.

Rensselæria marylandica Claypole=Newberrya claypolei.

Rensselæria marylandica Hall. Oriskany (Dev.).

Rensselæria marylandica Hall, Pal. New York, III, 1859, p. 461, pl. 108, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 258, pl. 76, figs. 8–20.

Loc. Cumberland, Maryland.

Rensselæria mutabilis Hall. Lower Helderberg (Dev.).

Meganteris mutabilis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 97.

Rensselæria mutabilis Hall, Pal. New York, III, 1859, p. 254, pl. 45, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 258, 259, figs. 178, 179; pl. 76, figs. 1–3a, 21, 22.

Loc. Albany and Columbia counties, New York.

Rensselæria ovalis Hall=Megalanteris ovalis.

Rensselæria ovoides (Eaton). Oriskany (Dev.).

Terebratula ovoides Eaton, Geological Text-Book, 1832, p. 45.

Terebratula perovalis Eaton, Ibidem, 1832, p. 45.

Atrypa elongata Conrad, Third Ann. Rep. N. Y. Geol. Survey, 1839, p. 65.—Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 123, fig. 2.—Hall, Ibidem, Fourth Dist., 1843, p. 138, fig. 2;—(Conrad) Fifteenth Rep. N. Y. State Cab. Nat. Hist., 1862, pl. 11, fig. 14.

Pentamerus deshayesii Castelnau, Essai Système Silurien l'Amérique Septentrionale, 1843, p. 38, pl. 15, figs. 1, 2.

Meganteris ovoides Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 102.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 826, fig. 649.

Rensselæria ovoides Hall, Pal. New York, III, 1859, p. 456, pl. 104, figs. 1–4; pl. 105, figs. 1–6.—Billings, Geol. Canada, 1863, p. 961, fig. 470;—Pal. Fossils, II, 1874, p. 41, pl. 3, figs. 7, 10.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 258, pl. 75, figs. 5–9; pl. 76, figs. 16, 18.

Loc. New York; Pennsylvania; Maryland; Virginia; Gaspé, Canada.

Rensselæria ovulum Hall and Clarke. Oriskany (Dev.).

Rensselæria ovulum Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 75, figs. 3, 4.

Loc. Cayuga, Canada.

Rensselæria portlandica Billings=Trigeria portlandica.

Rensselæria suessana Hall=Beachia suessana.

Rensselandia Hall=Newberrya.

RETICULARIA McCoy. Genotype Terebratula ? imbricata Sowerby.

Reticularia McCoy, Carboniferous Fossils of Ireland, 1844, p. 142.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 538.

Reticularia bicostata (Vanuxem). Niagara (Sil.).

Orthis bicostatus Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, pp. 91, 94.

Spirifer bicostatus Hall, Pal. New York, II, 1852, p. 263, pl. 54, fig. 4.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 19, 37, pl. 36, fig. 7.

Spirifera bicostata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 61, fig. 7.

Loc. Vernon Center, New York; Louisville, Kentucky.

Reticularia bicostata petila (Hall). Niagara (Sil.).

Spirifera bicostata? var. petila Hall, Descrip. n. sp. of Fossils from Waldron, Indiana, 1879, p. 15.

Spirifera bicostata var. petila Hall, Eleventh Rep. State Geol. Indiana, 1882, p. 279, pl. 27, figs. 8, 9;—Trans. Albany Institute, X, 1883, p. 71.

Digitized by Google

Reticularia bicostata petila (Hall)—Continued.

Spirifer bicostatus var. petilus Beecher and Clarke, Mem. N. Y. State M 1889, p. 75, pl. 6, figs. 1–3.

Loc. Waldron, Indiana.

Reticularia canandaiguæ (Hall and Clarke). Hamilton (

Spirifer canandaiguæ Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 37, figs. 23–25.

Loc. Centerfield and Canandaigua Lake, New York.

Reticularia clara (Swallow). Kaskaskia (L. C

Spirifera clara Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 86.

Loc. St. Genevieve County, Missouri.

Reticularia cooperensis (Swallow). Kinderhook (L. C

Spirifera cooperensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. Meek and Worthen, Geol. Survey Illinois, II, 1866, p. 155, pl. 14, fi Keyes, Geol. Survey Missouri, V, 1895, p. 78.

Spirifer hirtus White and Whitfield, Proc. Boston Soc. Nat. Hist., VIII, 1 293.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 21, 37, fig. 14 (? pl. 84, figs. 36, 37).

Spirifera semiplicata Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist p. 111.

Spirifer hirtus ? A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. Proc. American Phil. Soc., XII, 1870, p. 251.

Loc. Chouteau Springs, etc., Missouri; Rockford, Indiana; Burlington, Hickman County, Tennessee.

Reticularia fimbriata (Conrad). Oriskany-Ithaca (

Delthyris fimbriatus Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1 263.—Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 208, fig. 10.

Spirifer fimbriatus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 505, pl. 4, f Billings, Canadian Jour., VI, 1861, p. 257, figs. 68–70;—Geol. Canada p. 372, fig. 393.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, 20, 21, 33, 37, pl. 36, figs. 17–22; pl. 38, figs. 9, 10.

Spirifera fimbriata Hall, Pal. New York, IV, 1867, p. 214, pl. 33, figs. 1 Second Ann. Rep. N. Y. State Geol., 1883, pl. 61, figs. 17–22.—Whit Cont. Canadian Pal., I, 1892, p. 286.

Spirifer compactus Meek, Trans. Chicago Acad. Sci., I, 1868, p. 102, pl. 14,

Spirifer (Martinia) richardsoni Meek, Trans. Chicago Acad. Sci., I, 1868, pl. 14, fig. 2.

Spirifera (M.) richardsoni Whiteaves, Cont. Canadian Pal., I, 1891, p. Ibidem, 1892, p. 287, pl. 37, fig. 7.

Spirifera conradana Miller, American Pal. Foss., 2d ed., 1883, p. 372.—I roth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 1 7, figs. 11–13.

Spirifera (M.) undifera Walcott, Mon. U. S. Geol. Survey, VIII, 1884, pl. 3, 6; pl. 14, fig. 11.

Loc. New York; Ohio; Falls of Ohio; Illinois; Iowa; Maryland; Vir Eureka district, Nevada; Ontario and lakes Manitoba and Winnipe Mackenzie River, Northwest Territory, Canada.

Obs. Mr. Walcott is correct in regarding this species the same as S undiferus Roemer. Conrad's species, however, was published in 1842, that of Roemer is two years later, or in 1844. S. richardsoni is a specimen of S. compacta which Mr. Walcott has shown to be a synon S. undiferus. See Reticularia knappiana.

Digitized by Google

Reticularia franklini (Meek). Hamilton (Dev.).

Spirifer (Martinia) franklini Meek, Trans. Chicago Acad. Sci., I, 1868, p. 107, pl. 14, fig. 12.

Spirifera (M.) glabra var. franklini Whiteaves, Cont. Canadian Pal., I, 1891, p. 225.

Loc. Mackenzie River, Northwest Territory, Canada.

Obs. The type specimen in the U. S. National Museum collection proves to be closely related to Reticularia lævis Hall.

Reticularia guadalupensis (Shumard). Upper Carboniferous.

Spirifera guadalupensis Shumard, Trans. St. Louis Acad. Sci., I, 1859, p. 391.

Loc. Guadalupe Mountains, Texas.

Reticularia knappiana (Nettelroth). Corniferous (Dev.).

Spirifera knappiana Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 122, pl. 7, fig. 14.

Loc. Falls of Ohio.

Obs. Probably the same as R. fimbriata.

Reticularia lævis (Hall). Portage (Dev.).

Delthyris lævis Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 245, fig. 1.

Spirifera lævis Hall, Pal. New York, IV, 1867, p. 239, pl. 39, figs. 1–12.

Spirifer lævis Williams, American Jour. Sci., 3d ser., XX, 1880, p. 456.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 19, 33, 37, pl. 38, figs. 11–13; pl. 84, fig. 29.—Kindle, Bull. American Pal., 6, 1896, p. 36.

Spirifera (Martinia) glabra var. lævis Williams, Ann. New York Acad. Sci., II, 6, 1881, pl. 14, figs. 1, 2.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 140.

Loc. Ithaca and Cortlandville, New York.

Reticularia modesta (Hall). Lower Helderberg (Dev.).

Spirifer modestus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 61;—Pal. New York, III, 1859, p. 203, pl. 28, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 37, pl. 38, figs. 1, 3.

Loc. Cumberland, Maryland.

Reticularia nevadaensis (Walcott). Upper Devonian.

Spirifera (M.) glabra var. nevadensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 139, pl. 3, fig. 5; pl. 14, fig. 14.

Loc. Eureka district, Nevada.

Reticularia (?) nympha (Billings). Lower Helderberg (Dev.).

Spirifera nympha Billings, Proc. Portland Soc. Nat. Hist., I, 1863, p. 116, pl. 3, fig. 15.

Loc. Masardis, Maine.

Reticularia perplexa (McChesney). Upper Carboniferous.

Spirifer lineatus Shumard, Geol. Survey Missouri, 1855, p. 216.—Hall, Pacific R. R. Reports, III, 1856, p. 101, pl. 2, figs. 6–8.—Marcou, Geol. N. America, 1858, p. 50, pl. 7, fig. 5.—Newberry, Ives's Rep. Colorado River of the West, 1861, p. 127.—Swallow, Trans. St. Louis Acad. Sci., II, 1866, p. 408.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 10, 11, 17, 21, 30, 39, pl. 38, figs. 2, 4, 7, 8.

Spirifer perplexus McChesney, New Pal. Fossils, 1860, p. 43.

Spirifer lineatus? Meek, Geol. Survey California, I, 1864, p. 13, pl. 2, fig. 6.

Spirifer lineatus var. perplexus Swallow, Trans. St. Louis Acad. Sci., II, 1866, p. 408.

Spirifera lineata Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, pl. 2, fig. 3.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 230.

Spirifer (Martinia) perplexa Derby, Bull. Cornell Univ., I, 1874, p. 16, pl. 3, figs. 27, 39, 40, 45, 50; pl. 8, fig. 13.

Digitized by Google

Reticularia perplexa (McChesney)—Continued.

Spirifera (Martinia) lineata? White, Wheeler's Expl. and Survey west Meridian, III, Appendix, 1881.

Spirifera (Martinia) lineata White, Eleventh Rep. State Geol. Indiana, 18 372, pl. 42, figs. 4–6;—Thirteenth Rep. State Geol. Indiana, 1884, p. 1 27, figs. 4–6.—Herrick, Bull. Denison Univ., II, 1887, p. 46, pl. 1, fig. Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 603, pl. 16, figs. 3–5;— Ohio, VII, 1895, p. 488, pl. 12, figs. 3–5.

Spirifera perplexa Keyes, Geol. Survey Missouri, V, 1895, p. 84.

Loc. Ohio; Indiana; Illinois; Missouri; Iowa; Kentucky; California; T Pecos and Tigeras, New Mexico; Shasta County, California; Bomj and Itaituba, Brazil.

Obs. This species is not identical with Reticularia lineata Martin, as fou England and Belgium. Reticularia pseudolineata (Hall) is more c allied to that species than R. perplexa (McChesney).

Reticularia perplexa striatilineata (Swallow). Upper Carbonife

Spirifer lineatus var. striatolineatus Swallow, Trans. St. Louis Acad. Sc 1866, p. 408.

Loc. Missouri.

Obs. Regarded by Keyes as a synonym for R. perplexa.

Reticularia præmatura (Hall). Chemung (D

Spirifera præmatura Hall, Proc. American Philosophical Soc., X, 1866, p. 2 Pal. New York, IV, 1867, p. 250, pl. 33, figs. 31–35;—Second Ann. Rep. State Geol., 1883, pl. 61, figs. 23–25.

Martinia prematura Herrick, Geol. Ohio, VII, 1895, pl. 23, fig. 12.

Spirifer præmaturus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pl. 36, figs. 23–25.

Loc. Meadville and Oil Creek, Pennsylvania.

Reticularia pseudolineata (Hall). Burlington-Keokuk (L. Ca

Spirifer pseudolineatus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 645, p fig. 4.—?Herrick, Bull. Geol. Soc. America, II, 1891, p. 45, pl. 1, fig. 18.— and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 21, 37, pl. 36, figs. 28–

Spirifera lineatoides Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 645.

Spirifera pseudolineata Safford, Geol. Tennessee, 1869, p. 360.—Hall, Se Ann. Rep. N. Y. State Geol., 1883, pl. 61, figs. 28–30.

Reticularia pseudolineata Waagen, Palæontologica Indica, Ser. XIII, I, p. 542.

Spirifera lineatoides and pseudolineata Keyes, Geol. Survey Missouri, V, pp. 81, 82, pl. 40, fig. 6.

Loc. Keokuk, Iowa; Warsaw, Illinois; Crawfordsville, Indiana; Missouri.

Obs. See R. perplexa (McChesney).

Reticularia setigera (Hall). Kaskaskia (L. Ca

Spirifer setigerus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 705, pl. 27, fig Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 21, 37, pl. 36, figs. 2

Spirifera setigera Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl. 1877, p. 270, pl. 5, figs. 17, 18.—Hall, Second Ann. Rep. N. Y. State Geol., pl. 61, figs. 26, 27.—Keyes, Geol. Survey Missouri, V, 1895, p. 83.

Reticularia setigera Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p

Loc. Kaskaskia and Chester, Illinois; Caldwell and Crittenden counties, tucky; Oquirrh Mountains, Utah.

Obs. See R. translata.

Reticularia subundifera (Meek and Worthen). Hamilton (D

Spirifera subundifera Meek and Worthen, Geol. Survey Illinois, III, 1868, p. pl. 10, fig. 5.

Digitized by Google

Reticularia subundifera (Meek and Worthen)—Continued.

Spirifera (M.) undifera var. subundifera Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 145.

Loc. Rock Island, Illinois.

Reticularia (?) temeraria (Miller). Lower Carboniferous.

Spirifera temeraria Miller, Jour. Cincinnati Soc. Nat. Hist., IV, 1881, p. 314, pl. 7, fig. 9.

Loc. Lake Valley mining district, New Mexico.

Reticularia tenuispinata (Herrick). Waverly (L. Carb.).

Spirifera (Martinia) tenuispinata Herrick, Bull. Denison Univ., IV, 1888, p. 27, pl. 2, fig. 4.

Spirifer tenuispinatus Herrick, Geol. Ohio, VII, 1895, pl. 15, fig. 4.

Loc. Granville, Ohio.

Reticularia translata (Swallow). Kaskaskia (L. Carb.).

Spirifera translata Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 85.

Loc. Chester, Illinois; St. Marys, Missouri.

Obs. Regarded by Keyes as a synonym for R. setigera.

RETZIA King. Genotype Terebratula adrieni de Verneuil.

Retzia King, Mon. Permian Fossils, Pal. Soc., 1850, p. 137.—Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 53, figs. 1–3 on p. 55.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 103, figs. 80–100 on pp. 106, 107;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 787.

Obs. It is very probable that all of the species here referred to Retzia will prove to belong to other genera.

Retzia altirostris White=Eumetria altirostris.

Retzia chloe Billings=Parazyga hirsuta.

Retzia (?) circularis Miller. Chouteau (L. Carb.).

Retzia circularis Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 316, pl. 9, figs. 32–34.

Loc. Sedalia, Missouri.

Retzia compressa Meek=Hustedia mormoni.

Retzia dubia Billings=Trematospira dubia.

Retzia electra Billings=Rhynchospira electra.

Retzia eugenia Billings=Rhynchospira eugenia.

Retzia evax Hall=Homœospira evax.

Retzia formosa Whitfield=Rhynchospira formosa.

Retzia (?) granulifera Meek. Lorraine (Ord.).

Retzia (Trematospira) granulifera Meek, Proc. Acad. Nat. Sci. Philadelphia, 1872, p. 318;—Pal. Ohio, I, 1873, p. 128, pl. 11, fig. 6.

Trematospira (?) granulifera Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 61.

Loc. Cincinnati, Ohio.

Obs. This species is probably a rhynchonelloid.

Retzia hippolyte Billings=Trematospira hippolyte.

Retzia (?) jamesiana Rathbun. Middle Devonian.

Retzia jamesiana (Hartt) Rathbun, Bull. Buffalo Soc. Nat. Hist., I, 1874, p. 243, pl. 10, figs. 23, 27–38.

Retzia ? jamesiana Derby, Archives do Museu Nacional do Rio de Janeiro, IX, 1890, p. 79.

Retzia cf. jamesiana A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 68, pl. 4, fig. 14.

Loc. Erere and Rio Maecuru, Province of Para, Brazil; Bolivia.

Digitized by Google

Retzia marcyi Shumard=Eumetria marcyi.
Retzia meekana Shumard=Hustedia meekana.
Retzia mormoni Marcou=Hustedia mormoni.
Retzia osagensis Swallow=Acambona osagensis.
Retzia papillata Shumard=Hustedia papillata.

Retzia (?) plicata Miller. Chouteau (L. C

Retzia plicata Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, pl. 9, figs. 29–31.
Loc. Sedalia, Missouri.

Retzia polypleura A. Winchell. Portage (

Retzia polypleura A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862,
Loc. Port aux Barques, Michigan.

Retzia (?) popeana Swallow. ? Chouteau (L. C

Retzia (?) popeana Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 654.
Loc. Locality and formation not given.

Retzia punctulifera Shumard=Hustedia mormoni.
Retzia radialis Walcott (non Phillips)=Hustedia mormoni.
Retzia sexplicata White and Whitfield=Ptychospira sexplicata.
Retzia sobrina Beecher and Clarke=Homœospira sobrina.

Retzia (?) subglobosa Hall. Schoharie (

Rhynchospira subglobosa Hall, Pal. New York, IV, 1867, p. 421, pl. 63, figs. 23
Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 49, fig. 22.
Retzia subglobosa Miller, N. American Geol. and Pal., 1889, p. 367.
Loc. Schoharie, New York.

Retzia subglobosa McChesney=Hustedia mormoni.
Retzia triangularis Miller=Hustedia triangularis.
Retzia vera Hall=Eumetria marcyi.
Retzia vera costata Hall=Eumetria marcyi costata.
Retzia verneuiliana Hall=Eumetria marcyi.
Retzia ? wardiana Rathbun=Trigeria wardiana.
Retzia woosteri White=Eumetria woosteri.

RHINOBOLUS Hall. Genot. Rhynobolus sp. H.=?Obolus galtensis

Rhynobolus Hall, Notes on some New or Imperfectly Known Forms amor
Brachiopoda, 1871, p. 5;—Ibidem, 1872, p. 5, pl. 13, fig. 10;—Twenty
Rep. N. Y. State Cab. Nat. Hist., 1873, p. 247, pl. 13, fig. 10.—Waagen,
ontologica Indica, Ser. XIII, I, 1885, p. 761.—Hall and Clarke, Pal.
York, VIII, Pt. I, 1892, pp. 44, 46, 164;—Eleventh Ann. Rep. N. Y.
Geologist, 1894, p. 239.

Rhinobolus davidsoni Hall and Clarke. Niagara (

Rhinobolus davidsoni Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p
176, pl. 4B, figs. 10–12.
Loc. Near Grafton, Wisconsin.

Rhinobolus galtensis (Billings). Guelph (

Obolus galtensis Billings, Pal. Fossils, I, 1862, p. 168, fig. 153.
Obolellina galtensis Billings, Canadian Nat. Geol., VI, 1871, p. 222;—Ib
1872, p. 328.
Trimerella minor Dall, American Jour. Conch., VII, 1871, p. 83, pl. 11, fig.
?Rhynobolus sp.? Hall, Twenty-third Rep. N. Y. State Cab. Nat. Hist.,
p. 247, pl. 13, fig. 10.

Digitized by Google

Rhinobolus galtensis (Billings)—Continued.

Trimerella (?) galtensis Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 151, pl. 18, fig. 13; pl. 19, fig. 4.

Rhynobolus galtensis Whiteaves, Pal. Fossils, III, 1884, p. 7, pl. 2, fig. 1; pl. 8, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 45, pl. 4B, figs. 7–9.

Loc. Galt, Elora, Hespelar, and Durham, Ontario.

RHIPIDOMELLA Œhlert. Genotype Terebratula michelini L'Éveillé.

Rhipidomys Œhlert (non Wagnor, 1844), Fischer's Manuel de Conchyliologie, 1887, p. 1288.—Hall, Bull. Geol. Soc. America, I, 1889, p. 21.

Rhipidomella Œhlert, Journal de Conchyliologie, 1891, p. 372.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 209;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 271.

Rhipidomella alsa Hall. Schoharie (Dev.).

Orthis alsus Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 33;—Pal. New York, IV, 1867, p. 36, pl. 4, figs. 2–7.

Rhipidomella alsa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Albany County, New York.

Obs. Probably a synonym for R. peloris Hall.

Rhipidomella assimilis Hall. Lower Helderberg (Dev.).

Orthis assimilis Hall, Pal. New York, III, 1859, p. 175, pl. 15, fig. 1.

Rhipidomella assimilis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Loc. Schoharie, New York.

Rhipidomella burlingtonensis Hall. Burlington (L. Carb.).

Orthis michelini var. burlingtonensis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 596, pl. 12, fig. 4.

Rhipidomella burlingtonensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225, pl. 6A, fig. 13; pl. 20, figs. 5, 6.

Orthis burlingtonensis Keyes, Geol. Survey Missouri, V, 1895, p. 63, pl. 38, fig. 7.

Loc. Burlington, Iowa; Quincy, Illinois; Hannibal, Missouri.

Rhipidomella circulus Hall. Clinton (Sil.).

Orthis circulus Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 71, fig. 1;—Pal. New York, II, 1852, p. 56, pl. 20, fig. 6.—Billings, Canadian Nat. Geol., I, 1856, p. 134, pl. 2, fig. 1.

Rhipidomella circulus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 210, 224, pl. 6A, figs. 1, 2.

Loc. Reynales Basin, New York; Hamilton, Ontario.

Rhipidomella clarkensis (Swallow). Keokuk (L. Carb.).

Orthis clarkensis Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 81.

Rhipidomella clarkensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Clark County, Missouri.

Obs. Keyes regards this species as a synonym for Schizophoria swallovi.

Rhipidomella cleobis Hall. Onondaga (Dev.).

Orthis cleobis Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 35;—Pal. New York, IV, 1867, p. 41, pl. 5, figs. 9, 10.

Rhipidomella cleobis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Williamsville and Clarence, New York.

Rhipidomella cumberlandiæ Hall. Oriskany (Dev.).

Orthis cumberlandiæ Hall, Pal. New York, III, 1859, p. 481, pl. 95A, figs. 20, 21.

Rhipidomella cumberlandiæ Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Cumberland, Maryland.

Digitized by Google

Rhipidomella (?) cuneata (Owen). Hamilton (D

Orthis cuneata Owen, Geol. Survey Wisconsin, Iowa, and Minnesota, 18 585, pl. 3A, fig. 10.

Rhipidomella cuneata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p

Loc. New Buffalo, Iowa

Rhipidomella cyclas Hall. Marcellus and Hamilton (D

Orthis cyclas Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. Pal. New York, IV, 1867, p. 52, pl. 7, figs. 2, 3.

Rhipidomella cyclas Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p.

Loc. York, Pavilion, Bellona, etc., New York.

Rhipidomella dalyana (Miller). Burlington (L. Ca

Orthis dalyana Miller, Jour. Cincinnati Soc. Nat. Hist., IV, 1881, p. 313, pl. 7,

Rhipidomella dalyana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p

Loc. Lake Valley mining district, New Mexico.

Rhipidomella discus Hall. Lower Helderberg (D

Orthis discus Hall, Pal. New York, III, 1859, p. 165, pl. 10A, figs. 7–12.

Rhipidomella discus Hall and Clarke, Ibidem, VIII, Pt. I, 1892, pp. 210, 22

Loc. Hudson, Catskill, etc., New York; Square Lake, Maine.

Rhipidomella dubia Hall. St. Louis (L. Ca

Orthis dubius Hall, Trans. Albany Institute, IV, 1858, p. 12.—Whitfield, American Mus. Nat. Hist., I, 1882, p. 45, pl. 6, figs. 1–5.—Hall, Twelfth State Geol. Indiana, 1883, p. 324, pl. 29, figs. 1–5.

Orthis cooperensis Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 82.

Rhipidomella dubia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp 225, pl. 6A, figs. 18–22.

Orthis dubia Keyes, Geol. Survey Missouri, V, 1895, p. 64.

Loc. Spergen Hill and Bloomington, Indiana; Alton, Appanoose, etc., Illi Boonville and Barretts Station, Missouri; Keokuk, Iowa; Caldwell Co Kentucky.

Obs. Typical examples of R. cooperensis have been studied in Professor collection.

Rhipidomella eminens Hall. Lower Helderberg (D

Orthis eminens Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 42, 1, 2;—Pal. New York, III, 1859, p. 167, pl. 11, figs. 7–14.

Rhipidomella eminens Hall and Clarke, Pal. New York, VIII, Pt. I, 189 210, 225.

Loc. Schoharie, Carlisle, etc., New York.

Rhipidomella goodwini (Nettelroth). Hamilton (D

Orthis goodwini Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. vey, 1889, p. 39, pl. 17, figs. 30–32.

Loc. Falls of Ohio.

Rhipidomella hartti (Rathbun). Middle Devo

Orthis hartti Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 23.

Loc. Province of Para, Brazil.

Rhipidomella hybrida (Sowerby). Niagara (

Orthis hybrida Sowerby, Murchison's Silurian System, 1839, p. 630, pl. 1 11.—Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 105, fig. 7;—Pal. New II, 1852, p. 253, pl. 52, fig. 4.—Roemer, Die Silurische Fauna des West. nessee, 1860, p. 63, pl. 5, fig. 6.—Meek and Worthen, Geol. Survey Illi 1868, p. 371, pl. 7, fig. 7.—Hall, Twenty-eighth Rep. N. Y. State Mus. Hist., 1879, p. 149, pl. 21, figs. 18–25;—Eleventh Rep. State Geol. Ind 1882, p. 285, pl. 21, figs. 18–25;—Second Ann. Rep. N. Y. State Geol., 1883,

Digitized by Google

Rhipidomella hybrida (Sowerby)—Continued.

figs. 1-5.—Foerste, Bull. Denison Univ., I, 1885, p. 83, pl. 13, fig. 10.—Beecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 17, pl. 1, figs. 13-18.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 39, pl. 32, figs. 32-35.

Orthis hybrida? Hall, Trans. Albany Institute, IV, 1863, p. 209.

Rhipidomella hybrida Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 210, 224, pl. 6, figs. 1-5.

Orthis (Rhipidomella) hybrida Foerste, Geol. Ohio, VII, 1895, p. 584, pl. 25, fig. 10.

Loc. Europe; Lockport, etc., New York; Waldron, Indiana; Dayton, Ohio; Louisville, Kentucky; Perry County, Tennessee; Perry County, Missouri; Arisaig, Nova Scotia (Ami).

Rhipidomella idonea Hall. Hamilton (Dev.).

Orthis idonea Hall, Pal. New York, IV, 1867, p. 52, pl. 63, figs. 1-5.

Rhipidomella idonea Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Moscow and Eighteen Mile Creek, New York.

Rhipidomella inca (d'Orbigny). Devonian.

Orthis inca d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 38.

Spirifer inca d'Orbigny, Ibidem, 1842, pl. 2, figs. 10-12.

Loc. Cochabamba, Bolivia.

Rhipidomella leucosia Hall. Hamilton (Dev.).

Orthis leucosia Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 80;—Pal. New York, IV, 1867, pp. 48, 63, pl. 7, fig. 4; pl. 8, figs. 9, 10;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, fig. 16.

Rhipidomella leucosia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225, pl. 6, fig. 16; pl. 6A, fig. 9.

Loc. Eighteen Mile Creek, Canandaigua Lake, etc., New York; Cumberland, Maryland.

Rhipidomella livia (Billings). Corniferous (Dev.).

Orthis livia Billings, Canadian Journal, n. ser., V, 1860, p. 267, figs. 14-16;—Geol. Canada, 1863, p. 369, fig. 385.—Hall, Pal. New York, IV, 1867, p. 38, pl. 5, fig. 4.—Billings, Pal. Fossils, II, 1874, p. 32, figs. 14-16.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 40, pl. 16, figs. 23, 24; pl. 17, figs. 33-35.

Rhipidomella livia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Walpole, Ontario; New York; Columbus, Ohio; Falls of Ohio; Indian Cove, Gaspé.

Rhipidomella lucia (Billings). Oriskany (Dev.).

Orthis lucia Billings, Pal. Fossils, II, 1874, p. 35, pl. 3, fig. 4.

Rhipidomella lucia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Indian Cove, Gaspé.

Rhipidomella media (Shaler). Anticosti (Sil.).

Orthis media Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 65.—Billings, Catalogue Silurian Fossils of Anticosti, 1866, p. 41.

Loc. Anticosti.

Rhipidomella michelini (L'Éveillé). Waverly (L. Carb.).

Terebratula michelini L'Éveillé, Mém. Société Géol. de France, II, 1835, p. 39, pl. 2, figs. 14-17.

Orthis michelini Yandell and Shumard, Cont. Geol. Kentucky, 1847, p. 21.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 116.

Orthis michelini? A. Winchell, Proc. American Philosophical Soc., XII, 1870, p. 251.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, figs. 19-21.

Digitized by Google

Rhipidomella michelini (L'Éveillé)—Continued.

Rhipidomella michelini Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 194, 225, pl. 6A, fig. 12.

Loc. South of Louisville, and near Lebanon, Kentucky; Newark, Granville, etc., Ohio; Shafers, Pennsylvania; Lake Valley mining district, New Mexico.

Obs. It is probable that the American identifications of this species are the same as R. oweni Hall and Clarke.

Rhipidomella missouriensis (Swallow). Chouteau (L. Carb.).

Orthis missouriensis Swallow (non Shumard, 1855), Trans. St. Louis Acad. Sci., I, 1860, p. 639.

Rhipidomella missouriensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225, pl. 6A, figs. 16, 17.

Loc. Cooper and Marion counties, Missouri.

Rhipidomella (?) mitis (Hall). Schoharie (Dev.).

Orthis mitis Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 34;—Pal. New York, IV, 1867, p. 37.

Loc. Albany and Schoharie counties, New York.

Rhipidomella musculosa Hall. Oriskany (Dev.).

Orthis musculosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 46;—Pal. New York, III, 1859, p. 409, pl. 91, figs. 1–3; pl. 95, figs. 1–7.

Rhipidomella musculosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 190, 210, 225, pl. 6A, fig. 5.

Loc. Schoharie and Albany counties, New York; Cumberland, Maryland.

Rhipidomella nevadaensis (Meek). Carboniferous.

Orthis michelini (non L'Éveillé) var. Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 63, pl. 7, fig. 1.

Orthis nevadensis Meek, Ibidem, 1877; end of description.

Rhipidomella nevadensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. White Pine district, Nevada.

Rhipidomella oblata Hall. Lower Helderberg (Dev.).

Orthis oblata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 41, figs. 1–5;—Pal. New York, III, 1859, p. 162, pl. 10, figs. 1–22.—Whitfield, Geol. Wisconsin, IV, 1882, p. 320, pl. 25, figs. 1, 2.

Rhipidomella oblata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 210, 225, pl. 6A, figs. 3, 4.

Loc. Schoharie, Carlisle, Hudson, etc., New York; Waunakee, Wisconsin.

Rhipidomella oblata emarginata (Hall). Lower Helderberg (Dev.).

Orthis oblata var. emarginata Hall, Pal. New York, III, 1859, p. 164, pl. 10A, figs. 4–6.

Loc. Cumberland, Maryland.

Rhipidomella occasus Hall. Kinderhook (L. Carb.).

Orthis occasus Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 111.

Rhipidomella occasus Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Rockford, Indiana.

Obs. Compare with R. thiemei White.

Rhipidomella oweni Hall and Clarke. Waverly (L. Carb.).

Orthis (Rhipidomella) oweni Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 342, pl. 6, figs. 19–21.

Loc. Buttonmould Knobs, south of Louisville, Kentucky.

Obs. See R. michelini L'Éveillé.

Digitized by Google

Rhipidomella pecosi (Marcou). Upper Carboniferous.

Orthis pecosi Marcou, Geol. N. America, February 1858, p. 48, pl. 6, fig. 14.—White, Wheeler's Expl. Survey west 100th Meridian, IV, 1875, p. 125, pl. 9, fig. 5.—Kayser, Richthofen's China, IV, 1883, p. 177, pl. 24, fig. 1.—Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 573, pl. 56, figs. 1–3.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 129, pl. 32, figs. 20–22.—Keyes, Geol. Survey Missouri, V, 1895, p. 64.—Smith, Proc. American Phil. Soc., XXXV, 1897, p. 27 (extract).

Orthis carbonaria Swallow, Trans. St. Louis Acad. Sci., I, June, 1858, p. 218.—Meek, Final Rep. U. S. Geol. Survey Nebraska, 1872, p. 173, pl. 1, fig. 8.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 571, pl. 25, fig. 4.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 37, figs. 1–4.

Orthis sp. undet. Meek, Pal. California, I, 1864, p. 10, pl. 2, fig. 5.

Rhipidomella pecosi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 210, 226, pl. 7, figs. 1–4.

Loc. Throughout the Upper Carboniferous of North America; Lo-Ping, China; Amb, India.

Rhipidomella peloris Hall. Schoharie (Dev.).

Orthis peloris Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 32;—Pal. New York, IV, 1867, p. 34, pl. 4, figs. 1, 8–10.

Rhipidomella peloris Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225, pl. 6A, fig. 6.

Loc. Clarksville and Knox, New York.

Obs. Probably the same as R. alsa Hall.

Rhipidomella penelope Hall. Hamilton (Dev.).

Orthis penelope Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 79, figs. 1, 2;—Pal. New York, IV, 1867, p. 50, pl. 6, fig. 2;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, figs. 6–13.

Rhipidomella penelope Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 211, 225, pl. 6, figs. 6–13; pl. 6A, fig. 10 (?11).

Loc. Hamburg, Alexander, Pavilion, York, Moscow, etc., New York.

Rhipidomella penniana (Derby). Upper Carboniferous.

Orthis penniana Derby, Bull. Cornell Univ., I, 1874, p. 26, pl. 5, figs. 13, 15, 17, 19–22; pl. 8, fig. 2.

Rhipidomella penniana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 210, 225, pl. 7, figs. 5–10.

Loc. Bomjardim and Itaituba, Brazil.

Rhipidomella pennsylvanica (Simpson). Chemung (Dev.).

Orthis pennsylvanica Simpson, Trans. American Philosophical Soc., n. ser., XVI, 1889, p. 437, fig. 1.

Loc. Tioga and McKean counties, Pennsylvania.

Rhipidomella rhynchonelliformis (Shaler). Anticosti (Sil.).

Orthis rhynchonelliformis Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 66.—Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 42.

Loc. Anticosti.

Obs. Probably a variety of Rhipidomella uberis (Billings).

Rhipidomella semele Hall. Onondaga (Dev.).

Orthis semele Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 34;—Pal. New York, IV, 1867, p. 40, pl. 5, figs. 7, 8.

Rhipidomella semele Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Erie County, New York; Columbus, Ohio.

Digitized by Google

Rhipidomella solitaria Hall. Hamilton (Dev.).

Orthis solitaria Hall, Thirteenth Rep. New York State Cab. Nat. Hist., 1860, p. 80;—Pal. New York, IV, 1867, p. 45, pl. 7, fig. 1.

Rhipidomella solitaria Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. York, New York.

Rhipidomella subcirculus (Simpson). Clinton (Sil.).

Orthis subcircula Simpson, Trans. American Philosophical Soc., n. ser., XVI, 1889, p. 437, fig. 2.

Loc. Mifflin and Huntington counties, Pennsylvania.

Rhipidomella subelliptica (White and Whitfield). Kinderhook (L. Carb.).

Orthis subelliptica White and Whitfield, Proc. Boston Soc. Nat. Hist., VIII, 1862, p. 292.

Rhipidomella subelliptica Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Burlington, Iowa.

Rhipidomella suborbicularis Hall. Hamilton (Dev.).

Orthis suborbicularis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 486, pl. 2, fig. 1.

Rhipidomella suborbicularis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225.

Loc. Rock Island, Illinois.

Rhipidomella thiemei (White). Chemung (Dev.) and Kinderhook (L. Carb.).

Orthis thiemii, White, Jour. Boston Soc. Nat. Hist., VII, 1860, p. 231;—Twelfth Rep. Hayden's U. S. Geol. Survey Terr., 1883, p. 164, pl. 41, fig. 4.

Orthis thiemii? Hall, Pal. New York, IV, 1867, p. 63, pl. 8, fig. 2.

Rhipidomella thiemii Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225, pl. 6A, figs. 14, 15.

Loc. Burlington, Iowa; In the Chemung group at Leon, Napoli, and New Albion, New York.

Rhipidomella tubulistriata Hall. Lower Helderberg (Dev.).

Orthis tubulostriata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 42;—Pal. New York, III, 1859, p. 166, pl. 11, figs. 1–6.

Rhipidomella tubulostriata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 210, 225.

Loc. Albany County, New York.

Rhipidomella uberis (Billings). Anticosti (Sil.).

Orthis æquivalvis Shaler (non Hall, 1847), Bull. Mus. Comp. Zool., 4, 1865, p. 66.

Orthis uberis Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 42.

Rhipidomella uberis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 224.

Loc. Anticosti.

Obs. See Rhipidomella rhynchonelliformis (Shaler).

Rhipidomella vanuxemi Hall. Corniferous-Hamilton (Dev.).

Orthis vanuxemi Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 135, figs. 1–7;—Geol. Survey Iowa, I, Pt. II, 1858, p. 487, pl. 2, figs. 2, 3.—Billings, Canadian Jour., V, 1860, p. 269.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 409.—Billings, Geol. Canada, 1863, p. 384, fig. 417.—Hall, Pal. New York, IV, 1867, pp. 40, 47, pl. 5, fig. 6; pl. 6, fig. 3;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, figs. 14, 15.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 45, pl. 16, figs. 4–6, 12–14.—Herrick, Geol. Ohio, VII, 1895, pl. 20, fig. 10.

Digitized by Google

Rhipidomella vanuxemi Hall—Continued.

Rhipidomella vanuxemi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 225, pl. 6, figs. 14, 15; pl. 6A, figs. 7, 8.

Loc. New York; Columbus, Ohio; Falls of Ohio; Rock Island, Illinois; Buffalo, Iowa; Bosanquet, Ontario; Huron group, Port aux Barques, Michigan.

Rhipidomella vanuxemi pulchella (Herrick.) Waverly (L. Carb.).

Orthis vanuxemi var. pulchella Herrick, Bull. Denison Univ., III, 1888, p. 38, pl. 5, fig. 9.

Orthis vanuxemi var. gracilis Herrick, Geol. Ohio, VII, 1895, pl. 21, fig. 9.

Loc. Granville, Ohio.

RHYNCHONELLA Fischer de Waldheim. Genotype R. loxia Fischer de Waldheim.

Rhynchonella Fischer de Waldheim, Notice des Fos. Gouv. Moscou, 1809, p. 35, tab. II, figs. 5, 6.—Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 65.—Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 172, 1864, p. 70.—Hall, Pal. New York, IV, 1867, p. 332;—Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 269.—Dall, American Jour. Conch., VI, 1870, p. 151;—Ibidem, VII, 1871, p. 70.—Billings, Pal. Fossils, II, 1874, p. 35.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 72.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 177, 178;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 822.

Rhynchonella ænigma (d'Orbigny). Jurassic.

Terebratula ænygma d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 62, pl. 22, figs. 10–13.

Terebratula concinna (non Sowerby) Bayle and Coquand, Mém. Soc. Géol. France, ser. ii, IV, 1851, p. 23, pl. 8, figs. 4–6.

Rhynchonella ænigma Gottsche, Palæontographica, Suppl., III, 1878, p. 34.

Rhynchonella cfr. ænigma Steinman. Neues Jahrb. f. Min., Beilageband, 1881, p. 253.

Loc. Guasco, Coquimbo, Dona Ana, Chile; Copiapo, Caracoles, and Iquique, Peru.

Rhynchonella æquiplicata Gabb. Triassic.

Rhynchonella æquiplicata Gabb, Geol. Survey California, Pal., I, 1864, p. 35, pl. 6, fig. 37.

Loc. Cinnabar district, Humboldt Mountain, Nevada.

Rhynchonella æquiradiata Miller=Camarotœchia æquiradiata.

Rhynchonella æquivalvis Hall=Lissopleura æquivalvis.

Rhynchonella abrupta Hall=Uncinulus abruptus.

Rhynchonella acadiaensis Davidson. Upper Carboniferous.

Rhynchonella acadiensis Davidson, Quart. Jour. Geol. Soc. London, XIX, 1863, p. 172, pl. 9, fig. 16.—Dawson, Acadian Geol., 3d ed., 1878, p. 294, fig. 94.

Loc. Brookfield, Nova Scotia.

Rhynchonella acinus Hall=Camarotœchia acinus.

Rhynchonella acinus convexa Foerste=Camarotœchia acinus convexa.

Rhynchonella acutiplicata Hall. Lower Helderberg (Dev.).

Rhynchonella acutiplicata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 73, fig. 7;—Pal. New York, III, 1859, p. 232, pl. 33, fig. 3.

Loc. Schoharie, New York.

Digitized by Google

Rhynchonella (?) acutirostris Hall. Chazy (Ord.).

Atrypa acutirostra Hall, Pal. New York, I, 1847, p. 21, pl. 4 bis, fig. 6.

Rhynchonella acutirostris Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 65.

Loc. Chazy, New York.

Obs. This species is referred to Zygospira by Whitfield.

Rhynchonella ainsliei Winchell=Rhynchotrema ainsliei.

Rhynchonella algeri McChesney. Upper Carboniferous.

Rhynchonella algeri McChesney, New Pal. Fossils, 1860, p. 51.

Loc. Near New Harmony, Indiana.

Rhynchonella allegania Williams. Chemung (Dev.).

Rhychonella allegania Williams, Bull. U. S. Geol. Survey, 41, 1887, p. 87, pl. 4, figs. 1–8.

Loc. Olean and Little Genesee, New York; Bradford, Pennsylvania.

Rhynchonella alta Calvin=Pugnax pugnus alta.

Rhynchonella altilis Hall=Camarotœchia plena.

Rhynchonella altiplicata Hall. Lower Helderberg (Dev.).

Rhynchonella altiplicata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 72, figs. 1–4;—Pal. New York, III, 1859, p. 231, pl. 33, fig. 2.

Loc. Albany and Schoharie counties, New York.

Rhynchonella alveata Hall=Centronella alveata.

Rhynchonella ambigua Calvin. Middle Devonian.

Rhynchonella ambigua Calvin, Bull. U. S. Geol. and Geogr. Survey Terr., IV, 1878, p. 729.

Loc. Independence, Iowa.

Rhynchonella anduin Gottsche. Jurassic.

Terebratula ænigma (non d'Orb.) Darwin, Geol. Observations South America, 1846, pp. 215, 233, pl. 5, figs. 10–12.—Burmeister and Giebel, Abh. Naturf. Gessel. Halle, VI, 1862, p. 128.

Terebratula subtetræda (non Davidson) Conrad, U. S. Astronomical Exped. Southern Hemisphere, 1855, p. 282, pl. 42, fig. 8.

Rhynchonella anduin Gottsche, Palæontographica, Suppl., III, 1878, p. 34, pl. 4, figs. 4–7.

Loc. Iquique, Portezuelo de Manflas, and Cordillera de Dona Ana, Chile.

Rhynchonella angulata Geinitz (non Linné)=Enteletes hemiplicatus.

Rhynchonella (?) anticostiensis Billings. Lorraine (Ord.).

Rhynchonella anticostiensis Billings, Pal. Fossils, I, 1862, p. 142, fig. 119;—Geol. Canada, 1863, p. 211, fig. 212.

Rhynchonella (?) anticostiensis Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 464, fig. 34.

Rhynchonella anticostiensis var. Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 179.

Loc. Anticosti; Wilmington and Savanna, Illinois; Lattners, Iowa; Wisconsin; Manitoba.

Obs. Compare with R. argenturbica White.

Rhynchonella (?) antisiensis (d'Orbigny). Lower Devonian.

Terebratula antisiensis d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 36, pl. 2, figs. 26–28.

? Rhynchonella cf. antisiensis A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 57, pl. 4, figs. 1–7.

Loc. Cochabamba, Tarabuco, Bolivia.

Digitized by Google

Rhynchonella antonii Gabb. ?Cretaceous.
Rhynchonella antonii Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., IV, 1881, p. 299, pl. 42, fig. 10.
Loc. Cerro de San Antonio, and near Chota, Peru.

Rhynchonella arctirostrata Swallow. St. Louis (L. Carb.).
Rhynchonella arctirostrata Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 84.
Loc. Cooper County, Missouri.
Obs. Regarded by Keyes as a synonym for R. subcuneata = Camarophoria subcuneata.

Rhynchonella (?) argentea Billings. Anticosti (Sil.).
Rhynchonella ? argentea Billings, Catalogue Silurian Fossils Anticosti, 1866, p. 43.
Loc. Anticosti.

Rhynchonella argenturbica White=Rhynchotreta inæquivalvis.

Rhynchonella aspasia Billings. Lower Helderberg (Dev.).
Rhynchonella aspasia Billings, Proc. Portland Soc. Nat. Hist., I, 1863, p. 111, pl. 3, fig. 6.
Loc. Square Lake, Maine.

Rhynchonella barquensis A. Winchell. Marshall (L. Carb.).
Rhynchonella barquensis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 408.
Loc. Port aux Barques, Michigan.

Rhynchonella barrandi Hall=Camarotœchia barrandei.

Rhynchonella (?) belliformis Nettelroth. Niagara (Sil.).
Rhynchonella bellaforma Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 73.
Loc. Louisville, Kentucky.

Rhynchonella belemnitica Quenstedt. Jurassic.
Rhynchonella belemnitica (Quenst.) Moricke, N. Jahrb. f. Mineral., Beilageband, IX, 1894, p. 61.
For locality and observations see R. plicatissima.

Rhynchonella bialveata Hall. Lower Helderberg (Dev.).
Rhynchonella ? bialveata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 73;—Pal. New York, III, 1859, p. 233, pl. 34, figs. 1–4.
Loc. Albany County, New York; Square Lake, Maine.

Rhynchonella (?) bidens Hall. Clinton (Sil.).
Atrypa bidens Hall, Pal. New York, II, 1852, p. 69, pl. 23, fig. 3.
Rhynchonella bidens Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 77.
Loc. Lockport, New York.

Rhynchonella (?) bidentata (Hisinger). Niagara (Sil.).
Terebratula bidentata Hisinger, Kongl. Svenska Vet.-Akad. Handl., för 1825, 1826, p. 343, pl. 7, fig. 5.
Atrypa bidentata Hall, Pal. New York, II, 1852, p. 276, pl. 57, fig. 3.
Rhynchonella bidentata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist, 1859, p. 77.
Loc. Lockport, New York.

Rhynchonella billingsi Hall=Camarotœchia billingsi.

Rhynchonella booensis Shumard=Leiorhynchus booense.

Rhynchonella brevirostris Billings=Anastrophia brevirostris.

Digitized by Google

Rhynchonella camerifera A. Winchell. Marshall (L. Ca

Rhynchonella camerifera A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, p. 408.

Loc. Port aux Barques, Michigan.

Rhynchonella campbellana Hall=Uncinulus campbellanus.

Rhynchonella camura Hall=Trematospira camura.

Rhynchonella capax Hall=Rhynchotrema capax.

Rhynchonella caput-testudinis White=Camarophoria caput-testud

Rhynchonella caracolensis Gottsche. Jura

Rhynchonella caracolensis Gottsche, Palæontographica, Suppl., III, 1878, pl. 4, fig. 8.—Steinman, Neues Jahrb. f. Mineral., Beilageband, 1881, p. Möricke, Ibidem, Beilageband, IX, 1894, p. 61.

Loc. Iquique, Chile; Caracoles, Bolivia.

Rhynchonella carbonaria McChesney. Upper Carbonife

Rhynchonella carbonaria McChesney, New Pal. Fossils, 1860, p. 51.

Loc. Near Farmington, Illinois.

Rhynchonella carica Hall=Camarotœchia carica.

Rhynchonella carolina Hall=Camarotœchia carolina.

Rhynchonella castanea Meek=Hypothyris castanea.

Rhynchonella congregata Hall=Camarotœchia congregata.

Rhynchonella contracta Hall=Camarotœchia contracta.

Rhynchonella contracta var. saxatilis Hall=Camarotœchia contr saxatilis.

Rhynchonella colletti Miller. Niagara (

Rhynchonella colletti Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, p. 311, pl. 9, figs. 8, 9.

Loc. Wabash, Indiana.

Rhynchonella cooperensis Shumard. Kinderhook (L. Ca

Rhynchonella cooperensis Shumard, Geol. Rep. Missouri, 1855, p. 204, fig. 4.

?Camarophoria cooperensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p pl. 18, fig. 6.

Loc. Cooper County, Missouri; Eureka district, Nevada.

Rhynchonella (?) corinthia Billings. Calciferous (C

Rhynchonella corinthia Billings, Pal. Fossils, I, 1865, p. 220.

Loc. Table Head, Newfoundland.

Rhynchonella cuneata Billings, and Hall = Rhynchotreta cun americana.

Rhynchonella dawsoniana Davidson=Pugnax dawsoniana.

Rhynchonella (?) decemplicata Sowerby. Clinton (

Rhynchonella decemplicata Foerste, Proc. Boston Soc. Nat. Hist., XXIV, p. 320, pl. 6, figs. 23, 24.

Loc. England; Cumberland Gap, Tennessee.

Rhynchonella dentata Hall=Rhynchotrema dentatum.

Rhynchonella dotis Hall=Camarotœchia dotis.

Rhynchonella dryope Billings. Oriskany (D

Rhynchonella dryope Billings, Pal. Fossils, II, 1874, p. 37, pl. 3A, fig. 1.

Loc. Grand Greve, Gaspé.

Digitized by Google

Rhynchonella dubia Hall=Protorhyncha dubia.

Rhynchonella duplicata Hall=Camarotœchia duplicata.

Rhynchonella eatoniæformis McChesney=Pugnax rockymontana.

Rhynchonella emacerata Hall. Clinton (Sil.).

Atrypa emacerata Hall, Pal. New York, II, 1852, p. 71, pl. 23, fig. 6.—Dawson, Acadian Geology, 3d ed., 1878, p. 599.

Rhynchonella emacerata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 77.

Loc. Sodus and Rochester, New York; Arisaig, Nova Scotia.

Rhynchonella eminens Hall. Lower Helderberg (Dev.).

Rhynchonella eminens Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 78;—Pal. New York, III, 1859, p. 237, pl. 37, figs. 3, 4.

Loc. Albany County, New York.

Rhynchonella emmonsi Hall and Whitfield=Hypothyris emmonsi.

Rhynchonella endlichi Meek=Camarotœchia endlichi.

Rhynchonella ererensis Rathbun. Middle Devonian.

Rhynchonella ererensis Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 32.

Loc. Erere, Province of Para, Brazil.

Rhynchonella eurekaensis Walcott. Lower Carboniferous.

Rhynchonella eurekensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 223, pl. 18, fig. 8.

Loc. Eureka district, Nevada.

Rhynchonella (?) eva Billings. Anticosti (Sil.).

Rhynchonella eva Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 44.

Loc. Anticosti.

Rhynchonella evangelina Hartt. Upper Carboniferous.

Rhynchonella evangelina Hartt, Dawson's Acadian Geology, 3d ed., 1878, p. 299.

Loc. Windsor, Nova Scotia.

Obs. Compare with Pugnax pugnus as identified by Davidson, from the same locality.

Rhynchonella excellens Billings. Oriskany (Dev.).

Rhynchonella excellens Billings, Pal. Fossils, II, 1874, p. 36, figs. 17, 18.

Loc. Indian Cove, Gaspé.

Rhynchonella eximia Hall=Camarotœchia eximia.

Rhynchonella explanata McChesney=Camarophoria explanata.

Rhynchonella fitchana Hall. Oriskany (Dev.).

Rhynchonella fitchana Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 85;—Pal. New York, III, 1859, p. 441, pl. 103, fig. 1.

Loc. Carlisle, New York.

Rhynchonella formosa Hall=Rhynchotrema formosum.

Rhynchonella fringilla Billings=Camarotœchia fringilla.

Rhynchonella gainesi Nettelroth. Hamilton (Dev.).

Rhynchonella gainesi Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geological Survey, 1889, p. 76, pl. 31, figs. 6–9.

Loc. Jefferson County, Kentucky.

Rhynchonella glacialis Billings=Camarotœchia glacialis.

Rhynchonella glansfagea Hall=Centronella glansfagea.

Digitized by Google

Rhynchonella gnathophora Meek. Jurassic.

Rhynchonella gnathophora Meek, Geol. Survey California, Pal., I, 1864, p. 39, pl. 8, fig. 1.

Rhynchonella gnathophora? Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 284, pl. 7, fig. 6.

Loc. Plumas County, California; Uinta Range, Utah.

Rhynchonella greenana Ulrich=Leiorhynchus greeneanum.

Rhynchonella guadalupæ Shumard. Upper Carbonifcrous.

Rhynchonella guadalupe Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 295, pl. 11, fig. 6.

Loc. Guadalupe Mountains, New Mexico and Texas.

Rhynchonella halli Gabb. Triassic.

Rhynchonella halli Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., IV, 1860, p. 308, pl. 48, fig. 29.

Loc. Bath County, Virginia.

Rhynchonella heteropsis A. Winchell. Kinderhook (L. Carb.).

Rhynchonella heteropsis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 121.

Loc. Burlington, Iowa; Hamburg, Illinois; Medina County, Ohio.

Rhynchonella horsfordi Hall=Camarotœchia horsfordi.

Rhynchonella hubbardi A. Winchell. Marshall (L. Carb.).

Rhynchonella hubbardi A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 407;—Ibidem, 1865, p. 122.

Loc. Marshall and Port aux Barques, Michigan; Summit County, Ohio.

Rhynchonella huronensis A. Winchell. Huron (Dev.).

Rhynchonella huronensis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 409.

Loc. Port aux Barques, Michigan.

Rhynchonella huronensis precipua A. Winchell. Huron (Dev.).

Rhynchonella huronensis var. precipua A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 409.

Loc. Port aux Barques, Michigan.

Rhynchonella (?) hydraulica Whitfield. Waterlime (Sil.).

Rhynchonella hydraulica Whitfield, Annals N. Y. Acad. Sci., II, 1882, p. 194;—Ibidem, V, 1891, p. 512, pl. 5, fig. 17;—Geol. Ohio, VII, 1895, p. 414, pl. 1, fig. 17.

Loc. Greenfield, Ohio.

Rhynchonella ida Hartt. Upper Carboniferous.

Rhynchonella ida Hartt, Dawson's Acadian Geology, 3d ed., 1878, p. 298.

Loc. Windsor, Nova Scotia.

Rhynchonella illinoisensis Worthen. Upper Carboniferous.

Rhynchonella illinoisense Worthen, Bull. Illinois State Mus. Nat. Hist., 2, 1884, p. 24;—Geol. Survey Illinois, VIII, 1890, p. 104, pl. 11, fig. 3.

Loc. Peoria, Illinois.

Rhynchonella increbescens Hall, 1860 (non 1847)=Rhynchotrema capax.

Rhynchonella increbescens Hall=Rhynchotrema inæquivalve.

Rhynchonella indentata Shumard. Upper Carboniferous.

Rhynchonella indentata Shumard, Trans. St. Louis Acad. Sci., I, 1859, p. 393.

Loc. Guadalupe Mountains, New Mexico.

Rhynchonella indianensis Hall=Camarotœchia indianaensis.

Digitized by Google

Rhynchonella inæquiplicata Hall. Upper Helderberg (Dev.).
Rhynchonella inequiplicata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 126.
Loc. "Western New York."

Rhynchonella intermedia Barris=Hypothyris emmonsi.

Rhynchonella inutilis Hall. Lower Helderberg (Dev.).
Rhynchonella inutilis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 74;—Pal. New York, III, 1859, p. 223, pl. 34, figs. 7, 8.
Loc. Albany County, New York.

Rhynchonella (?) janea Billings. Lorraine and Anticosti (Ord. and Sil.).
Rhynchonella janea Billings, Catalogue Sil. Fossils Anticosti, 1866, p. 43.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 316, pl. 5, figs. 23, 24.
Loc. Anticosti; Collinsville, Alabama.

Rhynchonella kokomoensis Miller=Wilsonia kokomoensis.

Rhynchonella lacunosa (Schlotheim). Jurassic.
Terebratulites lacunosa Schlotheim, Leonhardt's Min. Tasch., VII, 1813, pl. 1, fig. 2.
Rhynchonella lacunosa Davidson, British Oolitic and Liassic Brach., Pal. Soc., 1852, p. 96, pl. 16, figs. 13, 14.—Aguilera, Datos para la Geologia de Mexico, 1893, p. 18;—Bol. Com. Geológica de Mexico, I, 1895, p. 1, pl. 1, figs. 1–13.
Loc. Europe; Rancho Alamitos, Sierra de Catorce, Mexico.

Rhynchonella lacunosa arolica Oppel. Jurassic.
Rhynchonella lacunosa var. arolica Aguilera, Datos para la Geologia de Mexico, 1893, p. 18;—Bol. Com. Geológica de Mexico, I, 1895, p. 1, pl. 1, figs. 14–25; pl. 2, figs. 1, 2.
Loc. Europe; Rancho Alamitos, Sierra de Catorce, Mexico.

Rhynchonella lævis Simpson. Clinton (Sil.).
Rhynchonella (Stenochisma) lævis Simpson, Trans. American Philosophical Soc., n. ser., XVI, 1889, p. 443, fig. 8.
Loc. Blair County, Pennsylvania.

Rhynchonella (?) lamellata Hall. Coralline (Sil.).
Atrypa lamellata Hall, Pal. New York, II, 1852, p. 329, pl. 74, fig. 11.
Rhynchonella lamellata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.
Loc. Schoharie, New York.

Rhynchonella laura Billings=Leiorhynchus laura.

Rhynchonella lingulata Gabb. Triassic.
Rhynchonella lingulata Gabb, Geol. Survey California, Pal., I, 1864, p. 34, pl. 6, fig. 36.
Loc. Humboldt County, Nevada.

Rhynchonella louisvillensis Nettelroth. Corniferous (Dev.).
Rhynchonella louisvillensis Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 77, pl. 31, figs. 1–4.
Loc. Falls of Ohio.

Rhynchonella macra Hall. St. Louis (L. Carb.).
Rhynchonella macra Hall, Trans. Albany Institute, IV, 1858, p. 11.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 52, pl. 6, figs. 40–42.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 334, pl. 29, figs. 40–42.
Loc. Alton, Illinois.

Digitized by Google

Rhynchonella mainensis Billings. Lower Helderberg (Dev.).

Rhynchonella mainensis Billings, Proc. Portland Soc. Nat. Hist., I, 1863, p. 110, pl. 3, fig. 4.

Loc. Square Lake, Maine.

Rhynchonella manflasensis Möricke. Jurassic.

Rhynchonella manflasensis Möricke, Neues Jahrb. f. Mineral., Beilageband, IX, 1894, p. 62, pl. 5, figs. 7a–7c.

Loc. Manflas and Melon, Chile.

Rhynchonella mansoni Salter=Atrypa mansonii.

Rhynchonella marshallensis A. Winchell=Camarotœchia marshallensis.

Rhynchonella maudensis Whiteaves. Cretaceous.

Rhynchonella maudensis Whiteaves, Mesozoic Fossils, Geol. Surv. Canada, I, 1884, p. 252, pl. 33, fig. 8.

Loc. Maud Island.

Rhynchonella medea Billings. Corniferous (Dev.).

Rhynchonella medea Billings, Canadian Jour., n. ser., V, 1860, p. 271;—Geol. Canada, 1863, p. 370, fig. 388.

Loc. Township of Rainham, Ontario.

Rhynchonella medialis Simpson. Waverly (L. Carb.).

Rhynchonella medialis Simpson, Trans. American Philosophical Soc., n. ser., XVI, 1889, p. 444, fig. 9.

Loc. Warren, Pennsylvania.

Rhynchonella (?) metallica White. Upper Carboniferous.

Rhynchonella metallica White, Wheeler's Expl. and Survey west 100th Merid., Prel. Rep., 1874, p. 20;—Ibidem, Final Rep., IV, 1875, p. 129, pl. 10, fig. 10.

Loc. Lincoln County, Nevada.

Obs. Probably an Uncinulus.

Rhynchonella mica Billings=Zygospira mica.

Rhynchonella (?) micropleura A. Winchell. Marshall (L. Carb.).

Rhynchonella (Retzia?) micropleura A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 122.

Loc. Battlecreek, Michigan.

Rhynchonella minnesotensis Sardeson=Rhynchotrema inæquivalvis.

Rhynchonella missouriensis Shumard, fig. 5a (non 5b, 5c)=Pugnax pugnus missouriensis.

Rhynchonella missouriensis Shumard, figs. 5b, 5c (non 5a)=Pugnax striaticostata.

Rhynchonella multistriata Hall. Oriskany (Dev.).

Rhynchonella multistriata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 85;—Pal. New York, III, 1859, p. 440, pl. 102, fig. 3; pl. 106, fig. 3.

Loc. Helderberg Mountains, New York.

Rhynchonella mutabilis Hall=Uncinulus mutabilis.

Rhynchonella mutata Hall=Pugnax mutata.

Rhynchonella myrina Hall and Whitfield. Jurassic.

Rhynchonella species? Meek and Hayden, Smithsonian Cont. to Knowl., XIV, 172, 1865, p. 71, pl. 4, fig. 3.

Rhynchonella myrina Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 284, pl. 7, figs. 1–5.—Whitfield, Powell's Geol. Geogr. Survey Rocky Mountain Region, 1880, p. 347, pl. 3, figs. 6, 7.

Loc. Uinta Range, Utah; Black Hills, Dakota.

Digitized by Google

Rhynchonella neenah Whitfield. Lorraine (Ord.).
Rhynchonella neenah Whitfield, Geol. Wisconsin, IV, 1882, p. 265, pl. 12, figs. 19–22.
Rhynchonella (?) neenah Winchell and Schuchert, Geol. Survey Minnesota, III, 1893, p. 465, pl. 34, figs. 35–37.
Loc. Ironridge, Clifton, etc., Wisconsin; Savanna, Illinois; Lattners, Iowa.

Rhynchonella neglecta Hall=Camarotœchia neglecta.

Rhynchonella neglecta var. scobina Meek=Camarotœchia neglecta.

Rhynchonella nitens Dana=Terebratula nitens.

Rhynchonella nobilis Hall=Uncinulus nobilis.

Rhynchonella nucleolata Hall=Uncinulus nucleolatus.

Rhynchonella nucula (Sowerby). Silurian.
Terebratula nucula Sowerby, Murchison's Silurian System, 1839, pl. 5, fig. 20.
Rhynchonella nucula Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 595.
Loc. England; Bessels Bay, lat. 81° 6′.

Rhynchonella nutrix Billings. Anticosti (Sil.).
Rhynchonella nutrix Billings, Catalogue Silurian Fossils Anticosti, 1866, p. 43.
Loc. Anticosti.

Rhynchonella oblata Hall. Oriskany (Dev.).
Rhynchonella oblata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 86;—Pal. New York, III, 1859, p. 439, pl. 102, figs. 1, 2.
Loc. Albany and Schoharie counties, New York.

Rhynchonella obsolescens Hall. Kinderhook (L. Carb.).
Rhynchonella (Eatonia) obsolescens Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 111.
Loc. Rockford, Indiana.

Rhynchonella obtusiplicata Hall=Camarotœchia obtusiplicata.

Rhynchonella occidens Walcott. Lower Devonian.
Rhynchonella occidens Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 152, pl. 15, fig. 3.
Loc. Eureka district, Nevada.

Rhynchonella opposita White and Whitfield. Kinderhook (L. Carb.).
Rhynchonella opposita White and Whitfield, Proc. Boston Soc. Nat. Hist., VIII, 1862, p. 294.
Loc. Burlington, Iowa.

Rhynchonella orbicularis Hall=Camarotœchia orbicularis.

Rhynchonella orientalis Billings. Chazy (Ord.).
Rhynchonella orientalis Billings, Canadian Nat. Geol., IV, 1859, p. 443, fig. 21;—Geol. Canada, 1863, p. 126, fig. 51.
Loc. Mingan Island.

Rhynchonella osagensis Swallow=Pugnax utah.

Rhynchonella ottumwa White=Pugnax ottumwa.

Rhynchonella parvini McChesney=Camarophoria subtrigona.

Rhynchonella perlamellosa Whitfield=Rhynchotrema perlamellosum.

Rhynchonella perrostellata Swallow. St. Louis (L. Carb.).
Rhynchonella perrostellata Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 85.
Loc. Cooper County, Missouri.

Digitized by Google

Rhynchonella persinuata A. Winchell. Kinderhook (L. Carb.).

Rhynchonella persinuata A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 121.

Loc. Burlington, Iowa.

Rhynchonella phoca Salter=Atrypa phoca.

Rhynchonella pipira Derby. Upper Carboniferous.

Rhynchonella pipira Derby, Bull. Cornell Univ., I, 1874, p. 24, pl. 3, figs. 18, 23, 25, 26, 31.

Loc. Bomjardim and Itaituba, Brazil.

Rhynchonella pisa Hall and Whitfield. Niagara (Sil.).

Rhynchonella pisa Hall and Whitfield, Pal. Ohio, II, 1875, p. 135, pl. 7, figs. 18–22.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geological Survey, 1889, p. 78, pl. 32, figs. 24–27.

Loc. Highland County, Ohio; Louisville, Kentucky.

Rhynchonella planiconvexa Hall. Lower Helderberg (Dev.).

Rhynchonella planoconvexa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 75;—Pal. New York, III, 1859, p. 235, pl. 34, fig. 22.

Loc. Albany County, New York.

Rhynchonella plena Hall=Camarotœchia plena.

Rhynchonella pleiopleura Hall=Camarotœchia pleiopleura.

Rhynchonella pleurodon (Phillips). Upper Carboniferous.

Terebratula pleurodon Phillips, Geol. Yorkshire, II, 1836, p. 222, pl. 12, figs. 25–30.

Rhynchonella pleurodon Davidson, Mon. British Carb. Brach., 1860, p. 101, pl. 23, figs. 1–15.—Toula, Sitzungsb. der k. k. Akad. zu Wien, LIX, 1869, p. 7, pl. 1, fig. 6.—Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 632.

Loc. Europe; "Common in the Carboniferous rocks of America," Davidson; Bolivia; Feilden Isthmus, lat. 82° 43′.

Obs. Compare with Pugnax utah (Marcou).

Rhynchonella plicata Hall. Medina (Sil.).

Atrypa plicata Hall, Pal. New York, II, 1852, p. 10, pl. 4, fig. 6.

Rhynchonella plicata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.

Loc. Lockport, New York.

Rhynchonella plicatella (Linné). Niagara (Sil.).

Atrypa plicatella? Hall, Pal. New York, II, 1852, p. 279, pl. 58, figs. 3, 4.

Rhynchonella plicatella Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.

Atrypa plicatella Miller, N. American Geol. Pal., 1889, p. 337.

Loc. Europe; Wolcott, New York.

Rhynchonella plicatilis (Sowerby). Cretaceous.

Terebratula plicatella Sowerby, Mineral Conchl., V, 1825, p. 167, tab. 503, fig. 1.

Rhynchonella plicatilis Davidson, British Cretaceous Brach., Pal. Soc., I, 1852, p. 75, pl. 10, figs. 37, 42.—Eichwald, Geog. Paleont. Bemerk. Halb. Mang. Aleutischen Inseln, 1871, p. 200.

Loc. England; Alaska.

Rhynchonella plicatissima Quenstedt. Jurassic.

Rhynchonella plicatissima (Quenst.) Möricke, Neues Jahrb. f. Mineral., Beilageband, IX, 1894, p. 61.

Loc. Sierra de la Ternera, Coquimbo, Guasco, and Copiapo, Chile.

Obs. Möricke says that Terebratula ænigma Forbes in great part belong to this species and R. belemnitica.

Digitized by Google

Rhynchonella plicifera Hall=Camarotœchia plena.

Rhynchonella principalis Hall. Oriskany (Dev.).

Rhynchonella principalis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 84;—Pal. New York, III, 1859, p. 443, pl. 106, fig. 4.

Loc. Auburn, New York.

Rhynchonella prolifica Hall=Camarotœchia prolifica.

Rhynchonella pugnus of authors=Pugnax pugnus.

Rhynchonella pustulosa White=Rhynchopora pustulosa.

Rhynchonella pyramidata Hall=Uncinulus pyramidatus.

Rhynchonella pyrrha Billings. Anticosti (Sil.).

Rhynchonella pyrrha Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 44.

Loc. Anticosti.

Rhynchonella ramsayi Hall. Oriskany (Dev.).

Rhynchonella ramsayi Hall, Pal. New York, III, 1859, p. 446, pl. 101A, figs. 7, 8.

Loc. Cumberland, Maryland.

Rhynchonella (?) raricosta Whitfield. Corniferous (Dev.).

Rhynchonella ? raricosta Whitfield, Annals N. Y. Acad. Sci., II, 1882, p. 201;—Ibidem, V, 1891, p. 522, pl. 6, fig. 6;—Geol. Ohio, VII, 1895, p. 421, pl. 2, fig. 6.

Loc. Columbus, Ohio.

Rhynchonella reticulata Hall=Dictyonella reticulata.

Rhynchonella ricinula Hall. St. Louis (L. Carb.).

Rhynchonella ricinula Hall, Trans Albany Institute, IV, 1858, p. 9.—Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 53, pl. 6, fig. 46.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 330, pl. 29, fig. 46.

Loc. Spergen Hill, Indiana.

Rhynchonella ringens Swallow=Camarophoria ringens.

Rhynchonella robusta Hall. Clinton (Sil.).

Atrypa robusta Hall, Pal. New York, II, 1852, p. 71, pl. 23, fig. 7.

Rhynchonella robusta Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.

Loc. Lockport, New York.

Rhynchonella rockymontana Marcou=Pugnax rockymontana.

Rhynchonella royana Hall. Corniferous (Dev.).

Rhynchonella ? (Stenocisma ?) royana Hall, Pal. New York, IV, 1867, p. 338, pl. 54, figs. 20–23.

Loc. Near Leroy, New York.

Rhynchonella rudis Hall. Lower Helderberg (Dev.).

Rhynchonella rudis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 75;—Pal. New York, III, 1859, p. 235, pl. 34, figs. 20, 21.

Loc. Hudson, New York.

Rhynchonella rugicosta Nettelroth. Niagara (Sil.).

Rhynchonella rugæcosta Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 78, pl. 32, figs. 48–51.

Loc. Louisville, Kentucky.

Rhynchonella saffordi Hall=Wilsonia saffordi.

Rhynchonella saffordi var. depressa=Wilsonia saffordi depressa.

Rhynchonella sageriana A. Winchell=Camarotœchia sageriana.

Rhynchonella sancta Sardeson=Rhynchotrema inæquivalve laticostatum.

Rhynchonella sappho Hall=Camarotœchia sappho.

Digitized by Google

Rhynchonella schucherti Stanton. Upper Cretaceous (Knox

Rhynchonella schucherti Stanton, Bull. U. S. Geol. Survey, 133, 1896, p. 31 figs. 1–4.

Loc. Paskenta, California.

Rhynchonella scobina Meek=Camarotœchia neglecta.

Rhynchonella semiplicata (Conrad). Lower Helderberg (

Atrypa semiplicata Conrad, Fifth Ann. Rep. Geol. Survey N. Y., 1841, p. 5

Rhynchonella semiplicata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1 65, figs. 1, 2;—Pal. New York, III, 1859, p. 224, pl. 29, fig. 1.

Loc. Schoharie and Carlisle, New York.

Rhynchonella septata Hall. Oriskany (

Rhynchonella septata Hall, Pal. New York, III, 1859, p. 443, pl. 103, fig. 2.

Loc. Albany County, New York.

Rhynchonella sordida Hall. Trenton (

Atrypa sordida Hall, Pal. New York, I, 1847, p. 148, pl. 33, fig. 16.

Rhynchonella sordida Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859,

Loc. Not given.

Rhynchonella speciosa Hall=Camarotœchia speciosa.

Rhynchonella stephani Hall=Camarotœchia stephani.

Rhynchonella (?) striata Simpson. Waverly (L. C

Rhynchonella striata Simpson, Trans. American Phil. Soc., n. ser., XVI, 1 444, fig. 10.

Loc. Near Warren, Pennsylvania.

Obs. Compare with Camarophoria ringens and C. caput-testudinis.

Rhynchonella striatocostata Meek and Worthen=Pugnax striatico

Rhynchonella stricklandi Sowerby=Uncinulus stricklandi.

Rhynchonella subacuminata Webster. Chemung (

Rhynchonella subacuminata Webster, American Naturalist, XXII, 1888, p

Loc. Near Rockford, Iowa.

Rhynchonella subcircularis A. Winchell. Marshall (L. C

Rhynchonella subcircularis A. Winchell, Proc. Acad. Nat. Sci. Philade 1862, p. 408.

Loc. Port aux Barques, Michigan.

Rhynchonella subcuneata Hall=Camarophoria subcuneata.

Rhynchonella subtetrædra (Conrad). ? Cretac

Terebratula subtetrædra Conrad, U. S. Astronomical Exped. Southern sphere, 1855, p. 282, pl. 42, fig. 8.

Loc. Portezuelo de Manplas and Cordillera de Dona Ana at an altitude of feet above the ocean.

Rhynchonella subtrigona Meek and Worthen=Camarophoria trigona.

Rhynchonella subtrigonalis Hall. Trenton (

Atrypa subtrigonalis Hall, Pal. New York, I, 1847, p. 145, pl. 33, fig. 12.

Rhynchonella subtrigonalis Hall, Twelfth Rep. N. Y. State Cab. Nat. 1859, p. 66.

Loc. Turin, New York.

Obs. Compare with Rhynchotrema inæquivalve.

Digitized by Google

Rhynchonella sulciplicata Hall. Lower Helderberg (Dev.).
Rhynchonella sulcoplicata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 76.—Pal. New York, III, 1859, p. 236, pl. 35, fig. 1.
Loc. Albany County, New York.

Rhynchonella tayloriana (Lea). ? Jurassic.
Terebratula tayloriana Lea, Trans. American Phil. Soc., n. ser., VII, 1841, p. 259, pl. 10, fig. 12.
Loc. Habana, Cuba.

Rhynchonella tennesseensis Hall (non Roemer)=Uncinulus stricklandi.

Rhynchonella tennesseensis Roemer. Niagara (Sil.).
Rhynchonella tennesseensis Roemer, Die Sil. Fauna des West. Tennessee, 1860, p. 72, pl. 5, fig. 14.—Hall and Whitfield, Twenty-seventh Rep. N. Y. State Cab. Nat. Hist., 1875, pl. 9, figs. 24–26;—Pal. Ohio, II, 1875, p. 136, pl. 7, figs. 16, 17.
Loc. Perry County, Tennessee; Louisville, Kentucky; Yellow Springs, Ohio.

Rhynchonella tethys Billings=Camarotœchia tethys.

Rhynchonella tetrædra (Sowerby). Liassic.
Terebratula tetrædra Sowerby, Mineral Conchology, I, 1812, p. 191, pl. 83, fig. 5.—Bayle and Coquand, Mém. Soc. Géol. France, ser. ii, IV, 1851, p. 17, pl. 7, figs. 9–10.
Rhynchonella tetrædra Davidson, British Oolitic and Liassic Brach., Pal. Soc., 1852, p. 93, pl. 18, figs. 5–10.—Behrendsen, Zeit. der Deuschen geol. Gessel., XLIII, 1891, p. 396.—Möricke, Neues Jahrb. f. Mineral., Beilageband, IX, 1894, p. 63.
Loc. Europe; Portezuelo Ancho, Argentine Republic; Manflas, Las Amolanas, etc., Chile.

Rhynchonella (?) tetraptyx A. Winchell. Kinderhook (L. Carb.).
Rhynchonella ? tetraptyx A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 120.
Loc. Rockford, Indiana.

Rhynchonella tenuistriata Nettelroth. Corniferous (Dev.).
Rhynchonella tenuistriata Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 82, pl. 7, figs. 27–29.
Loc. Falls of Ohio.

Rhynchonella texana Shumard. Upper Carboniferous.
Rhynchonella texana Shumard, Trans. St. Louis Acad. Sci., I, 1859, p. 393.
Loc. Mouth of Delaware Creek, Texas.

Rhynchonella thalia Billings=Camarotœchia billingsi.
Rhynchonella thera Walcott=Camarophoria thera.

Rhynchonella transversa Hall. Lower Helderberg (Dev.).
Rhynchonella transversa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 74, figs. 5, 6;—Pal. New York, III, 1859, p. 234, pl. 34, figs. 9–16.
Loc. Albany County, New York.

Rhynchonella triplicata Quenstedt. Jurassic.
Rhynchonella triplicata (Quenst.) Möricke, Neues Jahrb. f. Mineral., Beilageband, IX, 1894, p. 63.
Loc. Europe; Quebrada de la Iglesia, etc., Chile.

Digitized by Google

Rhynchonella tuta Miller. Burlington (L. Carb.).

Rhynchonella tuta Miller, Jour. Cincinnati Soc. Nat. Hist., IV, 1881, p. 315, pl. 7, fig. 11.

Loc. Lake Valley mining district, New Mexico.

Rhynchonella unica A. Winchell. Kinderhook (L. Carb.).

Rhynchonella unica A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 122.

Loc. Burlington, Iowa.

Rhynchonella unisulcata Hall=Pentagonia unisulcata.

Rhynchonella utah of authors=Pugnax utah.

Rhynchonella vellicata Hall=Uncinulus vellicatus.

Rhynchonella ventricosa Hall=Camarotœchia ventricosa.

Rhynchonella venustula Hall=Hypothyris cuboides.

Rhynchonella vicina Billings. Anticosti (Sil.).

Rhynchonella vicina Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 44.

Loc. Anticosti.

Rhynchonella (?) warrenensis Swallow. Lower Devonian.

Rhynchonella warrenensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 653.

Loc. Callaway County, Missouri.

Rhynchonella wasatchensis White=Seminula wasatchensis.

Rhynchonella whitiana Miller=Camarotœchia whitei.

Rhynchonella whitii Hall (non Winchell)=Camarotœchia whitei.

Rhynchonella whitei A. Winchell. Marshall (L. Carb.).

Rhynchonella whitei A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 407.

Loc. Marshall, Michigan.

Rhynchonella whitneyi Gabb. Cretaceous (Shasta).

Terebratella whitneyi Gabb, Geol. Survey California, Pal., II, 1869, p. 35, pl. 2, fig. 62.

Rhynchonella whitneyi Gabb, Ibidem, 1869, p. 204, pl. 34, fig. 105.—Stanton, Bull. U. S. Geol. Survey, 133, 1896, p. 32, pl. 1, figs. 5–10.

Loc. Napa and Colusa counties, California.

Rhynchonella wilmingtonensis (Lyell and Sowerby). Eocene.

Terebratula wilmingtonensis Lyell and Sowerby, Quart. Jour. Geol. Soc. London, I, 1845, p. 431.

Rhynchonella wilmingtonensis Conrad, American Jour. Conch., I, 1865, p. 35.

Loc. Wilmington, North Carolina.

Rhynchonella wilsoni Sowerby=Wilsonia wilsoni.

Rhynchonella wortheni Hall=Camarophoria wortheni.

RHYNCHOPORA King. Genotype Terebratula geinitziana de Verneuil.

Rhynchopora King, Ann. Mag. Nat. Hist., 2d ser., XVII, 1856, p. 506.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 210;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 832.

Rhynchoporina Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1305.

Rhynchopora pustulosa (White). Kinderhook (L. Carb.).

Rhynchonella pustulosa White, Jour. Boston Soc. Nat. Hist., VIII, 1860, p. 226.—Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 257, pl. 4, figs. 12–14.

Rhynchopora pustulosa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 210, pl. 58, figs. 1–4.

Loc. Burlington, Iowa; Wasatch Range, Utah; Lake Valley mining district, New Mexico (Miller).

Digitized by Google

RHYNCHOSPIRA Hall. Genotype Waldheimia formosa Hall.

Rhynchospira Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 29;—Pal. New York, III, 1859, pp. 213, 484;—Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 58, figs. 12–17;—Pal. New York, IV, 1867, p. 276.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 108, fig. 101;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 791.

Retzia Billings, Canadian Journal, VI, 1861, p. 147.

Rhynchospira (?) acadiæ (Hall). Arisaig (Sil.).

Trematospira acadiæ Hall, Canadian Nat. Geol., V, 1860, p. 146, fig. 4.—Dawson, Acadian Geology, 3d ed., 1878, p. 597.

Loc. Nova Scotia.

Rhynchospira aprinis Hall=Homœospira apriniformis.

Rhynchospira (?) ashlandensis Herrick. Waverly (L. Carb.).

Rhynchospira ? ashlandensis Herrick, Bull. Denison Univ., IV, 1888, p. 25, pl. 3, fig. 16;—Geol. Ohio, VII, 1895, pl. 23, fig. 16.

Loc. Lyon Falls, Ohio.

Rhynchospira electra (Billings). Lower Helderberg (Dev.).

Retzia electra Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 114, pl. 3, fig. 11.

Rhynchospira electra Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 111, pl. 50, figs. 29–31.

Loc. Square Lake, Maine.

Rhynchospira equiradiata Hall=Camarotœchia æquiradiata.

Rhynchospira (?) eugenia (Billings). Corniferous (Dev.).

Retzia eugenia Billings, Canadian Jour., VI, 1863, p. 147, fig. 58;—Geol. Canada, 1863, p. 373, fig. 395.

Rhynchospira (?) eugenia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 111, pl. 50, figs. 41–43.

Loc. Walpole, Ontario.

Rhynchospira evax Hall=Homœospira evax.

Rhynchospira formosa Hall. Lower Helderberg (Dev.).

Waldheimia formosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 88.

Trematospira (Rhynchospira) formosa Hall, Pal. New York, III, 1859, p. 215, pl. 36, fig. 2; pl. 95A, figs. 7–11.

Rhynchospira formosa Hall, Pal. New York, IV, 1867, p. 278, figs. 1–6.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 109, fig. 101, pl. 50, figs. 21–25.

Retzia formosa Miller, N. American Geol. Pal., 1889, p. 366.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 512, pl. 5, figs. 15, 16;—Geol. Ohio, VII, 1895, p. 413, pl. 1, figs. 15–16.

Loc. Helderberg Mountains, New York; Square Lake, Maine; Greenfield, Ohio.

Rhynchospira globosa Hall. Lower Helderberg (Dev.).

Waldheimia globosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 87.

Trematospira (Rhynchospira) globosa Hall, Pal. New York, III, 1859, p. 215, pl. 36, fig. 1.

Rhynchospira globosa Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 111.

Loc. Helderberg Mountains, New York.

Rhynchospira (?) helena (Nettelroth). Niagara (Sil.).

Trematospira helena Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 137, pl. 32, figs. 40–43.

Loc. Louisville, Kentucky.

Rhynchospira lepida Hall=Trigeria lepida.

Digitized by Google

Rhynchospira nobilis Hall=Cyclorhina nobilis.

Rhynchospira rectirostris Hall. Oriskany (

Waldheimia rectirostra Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857

Trematospira (Rhynchospira) rectirostra Hall, Pal. New York, III, 1859, pl. 95A, fig. 1, and p. 485.

Rhynchospira rectirostra Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 1

Loc. Cumberland, Maryland.

Rhynchospira scansa Hall and Clarke. Waverly (L. C

Rhynchospira scansa Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, fig. 45.

Loc. McKean County, Pennsylvania.

Rhynchospira (?) sinuata Hall. Arisaig

Rhynchospira sinuata Hall, Canadian Nat. Geol., V, 1860, p. 146.—D Acadian Geology, 3d ed., 1878, p. 597.

Retzia sinuata Miller, N. American Geol. Pal., 1889, p. 367.

Loc. Arisaig, Nova Scotia.

Rhynchospira subglobosa Hall=Retzia subglobosa.

RHYNCHOTREMA Hall. Genotype Rhynchonella capax Co

Rhynchotrema Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, figs. 12–14.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 458. and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 182;—Thirteenth An N. Y. State Geologist, 1895, p. 825.

Rhynchotrema ainsliei N. H. Winchell. Trenton (

Rhynchonella ainsliei N. H. Winchell, Fourteenth Ann. Rep. Geol. Nat Survey Minnesota, 1886, p. 315, pl. 2, figs. 5, 6.

Rhynchotrema ainsliei Winchell and Schuchert, Minnesota Geol. Surve 1893, p. 459, pl. 34, figs. 1–8.

Loc. Minneapolis, St. Paul, etc., Minnesota; Decorah, Iowa.

Rhynchotrema capax (Conrad). Lorraine (

Atrypa capax Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 264, fig. 21.

Atrypa increbescens (partim) Hall, Pal. New York, I, 1847, p. 146, pl. 3 13i, 13k–13y.—Billings, Canadian Nat. Geol., I, 1856, p. 207, figs. 15, 16.- Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 66. figs. 6, 7, 9–11.

Rhynchonella increbescens (partim) Hall, Geol. Wisconsin, I, 1862, p. 1 11, fig. 2.

Rhynchonella capax Billings, Geol. Canada, 1863, p. 211, fig. 213.—Mee Ohio, I, 1873, p. 123, pl. 11, fig. 2.—Miller, Cincinnati Quart. Jour. S 1875, p. 17.—White, Second Ann. Rep. Indiana Bureau of Statisti Geol., 1880, p. 489, pl. 1, figs. 9–11;—Tenth Rep. State Geol. Indiana p. 121, pl. 1, figs. 9–11.—Whitfield, Geol. Wisconsin, IV, 1882, p. 263, figs. 26, 27.—Keyes, Geol. Survey Missouri, V, 1895, p. 99, pl. 41, fig. 1

Rhynchotrema capax Winchell and Schuchert, Minnesota Geol. Surve 1893, p. 462, pl. 34, figs. 30–34.—Hall and Clarke, Pal. New York, VI II, 1893, pp. 183, 185, pl. 56, figs. 14–18, 20–27; pl. 83, fig. 31.—Whiteave Foss., III, Pt. III, 1897, p. 178.

Loc. Richmond, Indiana; Oxford, etc., Ohio; Wilmington, Illinois; Girardeau, Missouri; Stockbridge, Ironridge, etc., Wisconsin; La Iowa; Spring Valley, Minnesota; Anticosti; Lake Winnipeg, Man Fort Churchill, Hudson Bay.

Digitized by Google

Rhynchotrema dentatum Hall. Trenton and Lorraine (Ord.).

Atrypa dentata Hall, Pal. New York, I, 1847, p. 148, pl. 33, fig. 14.

Rhynchonella dentata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 65.—Meek, Pal. Ohio, I, 1873, p. 121, pl. 11, fig. 3.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 18.—White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, p. 490, pl. 1, figs. 12–14;—Tenth Rep. State Geol. Indiana, 1881, p. 122, pl. 1, figs. 12–14.

Rhynchotrema dentata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 185.

?Rhynchonella dentata Keyes, Geol. Survey Missouri, V, 1895, p. 100, pl. 41, fig. 3.

Loc. Turin, New York; Dayton and Oxford, Ohio; Richmond, Indiana; near Nashville, Tennessee.

Rhynchotrema formosum (Hall). Lower Helderberg (Dev.).

Rhynchonella formosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 76, figs. 1–5;—Pal. New York, III, 1859, p. 236, pl. 35, fig. 6.

Stenocisma formosa Hall, Pal. New York, IV, 1867, p. 334.—Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 187, pl. 56, figs. 41–45.

Loc. Schoharie and Albany counties, New York; Lake Temiscouata, New Brunswick, and Arisaig, Nova Scotia (Ami).

Rhynchotrema inæquivalve (Castelnau). Trenton (Ord.).

Spirifer inæquivalvis Castelnau, Essai Système Sil. l'Amérique Septentrionale, 1843, p. 40, pl. 14, fig. 8.

Atrypa increbescens (partim) Hall, Pal. New York, I, 1847, pp. 146, 289, pl. 33, figs. 13a–13h; ?pl. 79, fig. 6.

Rhynchonella increbescens (partim) Billings, Canadian Nat. Geol., I, 1856, p. 207, figs. 11–14.—Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 66.—Billings, Geol. Canada, 1863, p. 168, fig. 153.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 83, pl. 34, figs. 26–29.

Rhynchonella argenturbica White, Wheeler's Expl. and Survey west 100th Merid., IV, Ptel. Rep., 1874, p. 14;—Ibidem, Final Rep., 1875, p. 75, pl. 4, fig. 12.

Trematospira (?) quadriplicata Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 60, figs. 6, 7.

Rhynchotreta quadriplicata Miller, N. American Geol. Pal., 1889, p. 370.

Rhynchonella minnesotensis Sardeson, Bull. Minnesota Acad Nat. Sci., III, 1892, p. 333, pl. 4, figs. 21–23.

Rhynchotrema inæquivalvis Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 459, pl. 34, figs. 9–25.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 179.

Rhynchotrema increbescens Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 183, 185.

Loc. Drummonds Island (Castelnau); New York; Kentucky; Tennessee; Illinois; Wisconsin; Iowa; Minnesota; Silver City, New Mexico; Ottawa, Canada; Lake Winnipeg, Manitoba.

Obs. Compare Rhynchonella subtrigonalis.

Rhynchotrema inæquivalve laticostatum Win. and Schuch. Trenton (Ord.).

Rhynchotrema inæquivalvis var. laticostata W. and S., American Geol., IX, April 1, 1892, p. 293;—Minnesota Geol. Survey, III, 1893, p. 461, pl. 34, figs. 26–29.

Rhynchonella sancta Sardeson, Bull. Minnesota Acad. Nat. Sci., III, April 9, 1892, p. 333, pl. 4, figs. 19, 20.

Loc. Cannon Falls, Minnesota.

Rhynchotrema ottawaense (Billings). Trenton (Ord.).

Porambonites? ottawaensis Billings, Pal. Fossils, I, 1862, p. 140, fig. 117.

Digitized by Google

Rhynchotrema ottawaense (Billings)—Continued.

Protorhyncha? and Orthorhynchula? ottawaensis Hall and Clarke, Pal. York, VIII, Pt. II, 1893, pp. 181, 228.

Loc. Pauquette Rapids, Canada; near Murfreesboro, Tennessee.

Rhynchotrema perlamellosum (Whitfield). Lorraine (O

Rhynchonella perlamellosa Whitfield, Ann. Rep. Geol. Survey Wisconsin, p. 73.—James, The Palæontologist, 2, 1878, p. 15.—Whitfield, Geol. Wi sin, IV, 1882, p. 265, pl. 12, figs. 23–25.

Loc. Delafield and Iron Ridge, Wisconsin; Oxford, Ohio.

RHYNCHOTRETA Hall. Genotype Rhynchonella cuneata Dal

Rhynchotreta Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p figs. 1–4;—Eleventh Rep. State Geol. Indiana, 1882, p. 309.—Nettelroth, tucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 84.—Hal Clarke, Pal. New York, VIII, Pt. II, 1893, p. 185;—Thirteenth Ann. Rep. State Geologist, 1895, p. 825.

Rhynchotreta cuneata americana Hall. Niagara (

Atrypa cuneata Hall (non Dalman), Geol. N. Y.; Rep. Fourth Dist., 1843, of Organic Remains, 13, figs. 3, 4;—Pal. New York, II, 1852, p. 276, p fig. 4.—Billings, Canadian Nat. Geol., I, 1856, p. 138, pl. 2, fig. 13.

Rhynchonella cuneata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., p. 77.—Billings, Geol. Canada, 1863, p. 315, fig. 323.

Rhynchotreta cuneata var. americana Hall, Twenty-eighth Rep. N. Y. Mus. Nat. Hist., 1879, p. 167, pl. 25, figs. 29–38;—Eleventh Rep. State Indiana, 1882, p. 310, pl. 25, figs. 29–38.—Nettelroth, Kentucky Fossil S Mem. Kentucky Geol. Survey, 1889, p. 85, pl. 32, figs. 58, 59, 62, 63.—Be and Clarke, Mem. N. Y. State Mus., I, 1889, p. 47, pl. 4, figs. 12–22.— and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 187, pl. 56, figs. 31-38

Loc. Lockport, etc., New York; Hamilton, Ontario; Waldron and Os Indiana; Louisville, Kentucky; Milwaukee, Wisconsin.

Rhynobolus Hall=Rhinobolus.

RŒMERELLA Hall and Clarke. Genotype Orbicula grandis Va

Rœmerella Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 137, fig. Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 257.

Rœmerella grandis (Vanuxem). Hamilton (D

Orbicula grandis Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 152, fig.

Discina grandis Hall, Pal. New York, IV, 1867, p. 17, pl. 1, fig. 18; pl. 2, 32, 33.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Su 1889, p. 33, pl. 3, fig. 3.

Discina (Orbiculoidea?) grandis Hall and Whitfield, Twenty-fourth Rep. State Cab. Nat. Hist., 1872, p. 187;—Twenty-seventh Rep. Ibidem, 187 9, figs. 33–35.

Rœmerella grandis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 13 65, pl. 4E, figs. 29–31.

Loc. Cazenovia and Pratts Falls, New York; Columbus, Ohio; Falls of Oh

ROMINGERINA Hall and Cl. Genotype Centronella julia A. Winc

Romingerina Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 272;— teenth Ann. Rep. N. Y. State Geologist, 1895, p. 855.

Romingerina julia (A. Winchell). Waverly (L. Ca

Centronella julia A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 4 Ibidem, 1865, p. 123.—Hall, Pal. New York, IV, 1867, p. 419, pl. 61A, 41–46.—Herrick, Bull. Denison Univ., III, 1888, p. 49, pl. 2, fig. 5.

Digitized by Google

Romingerina julia (A. Winchell)—Continued.

Romingerina julia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 271, figs. 187, 188, pl. 79, figs. 28–30.

Loc. Port Aux Barques, Michigan; Cuyahoga and Licking counties, Ohio. ?In the Chemung at Rushford, New York (Williams).

SCAPHIOCŒLIA Whitfield. Genotype S. boliviaensis Whitfield.

Scaphiocœlia Whitfield, Trans. American Inst. Min. Engi., XIX, 1891, p. 106.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 275;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 857.

Scaphiocœlia boliviaensis Whitfield. Middle Devonian.

Scaphiocœlia boliviensis Whitfield, Trans. American Inst. Min. Engi., XIX, 1891, p. 106, figs. 1–4.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 276, figs. 193–196.

Loc. Sercre or Quechista, Bolivia.

SCENIDIUM Hall. Genotype Orthis insignis Hall.

Skenidium Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 70, figs. 1–5.—Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 549.

Scenidium Œhlert, Bull. Societe d'Etudes Scientifiques d'Angers, 1887, p. 4, extract.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 241.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 381.—Hall and Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 276.

Scenidium anthonense Sardeson. Trenton (Ord.).

Skenidium halli Safford, Geol. Tennessee, 1869, p. 287 (undefined).

Skenidium anthonensis Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 333, pl. 4, fig. 7.

Scenidium halli Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 242, pl. 7A, figs. 33–39.

Scenidium anthonensis Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 381, figs. 20–23.

Loc. Minneapolis, St. Paul, and Cannon Falls, Minnesota; Dixon, Illinois; Lebanon, Tennessee.

Scenidium devonicum Walcott=Dalmanella devonica.

Scenidium halli Safford=S. anthonense.

Scenidium insigne Hall. Lower Helderberg (Dev.).

Orthis insignis Hall, Pal. New York, III, 1859, p. 173.

Skenidium (Orthis) insignis Hall, Ibidem, 1859, pl. 10A, figs. 13–15.

Skenidium insignis Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 70, figs. 1–5;—Second Ann. Rep. N. Y. State Geol., 1883, p. 37, figs. 31–35.

Scenidium insigne Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 242, pl. 7, figs. 31–35.

Loc. Helderberg Mountains, New York; Perry County, Tennessee.

Scenidium (?) merope (Billings). Trenton and Lorraine (Ord.).

Orthis merope Billings, Pal. Fossils, I, 1862, p. 139, fig. 116.

Scenidium ? merope Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 242, pl. 7A, figs. 31, 32.

Loc. Ottawa, Canada; Cincinnati, Ohio; Burgin, Kentucky.

Scenidium pyramidale Hall. Niagara (Sil.).

Orthis pyramidalis Hall, Pal. New York, II, 1852, p. 251, pl. 52, fig. 2.

Skenidium pyramidalis Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 70.

Skenidium pyramidata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 37, figs. 29, 30,

Digitized by Google

Scenidium pyramidale Hall—Continued.

Scenidium pyramidale Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. pl. 7, figs. 29, 30; pl. 7A, figs. 40–42.

Loc. Lockport, New York; Arisaig, Nova Scotia (Ami).

SCHIZAMBON Walcott. Genotype S. typicalis Walc

Schizambon Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 69.—Hall Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 113, 167.—Winchell and Sc chert, Minnesota Geol. Survey, III, 1893, p. 360.—Hall and Clarke, Eleve Ann. Rep. N. Y. State Geologist, 1894, p. 253.

Schizambonia Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1266.

Schizambon (?) dodgei Winchell and Schuchert. Trenton (Or

Schizambon (?) dodgii W. and S., Minnesota Geol. Survey, III, 1893, p. pl. 30, figs. 5–7.

Loc. Sandyhill, New York.

Schizambon (?) fissus canadaensis (Ami). Utica (Or

Siphonotreta scotica Whiteaves, American Jour. Sci., 3d ser., XXIV, 1882 278;—Canadian Nat. Geol., X, 1883, p. 396.

Siphonotreta scotica var. canadensis Ami, Ottawa Naturalist, I, 1887, p. 124.

Schizambon (?) fissus var. canadensis Hall and Clarke, Pal. New York, V Pt. I, 1892, p. 115, pl. 4, figs. 32–36.

Loc. Gloucester, Ontario.

Schizambon (?) lockei Winchell and Schuchert. Lorraine (Or

Schizambon (?) lockii Winchell and Schuchert, Minnesota Geol. Survey, 1893, p. 362, pl. 30, figs. 8–10.

Loc. Cincinnati, Ohio.

Schizambon typicalis Walcott. Pogonip or Calciferous (Or

Schizambon typicalis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 70, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 114, fig. pl. 4, figs. 27–30.

Loc. Eureka district, Nevada; Manitou, Colorado.

SCHIZOBOLUS Ulrich.

Genotype Discina truncata Hall=Lingula concentrica Vanux

Schizobolus Ulrich, Cont. American Pal., I, 1886, p. 25, pl. 3, fig. 3.—Hall Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 87, 165;—Eleventh Ann. N. Y State Geologist, 1894, p. 246.

Schizobolus concentricus (Vanuxem). Genesee (De

Lingula concentrica Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 168, fig. Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 223, fig. 4.

Discina truncata Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 2 Pal. New York, IV, 1867, p. 23, pl. 1, fig. 15; pl. 2, figs. 36, 37.

Discina (Trematis) truncata Hall and Whitfield, Twenty-fourth Rep. N. Y. S Cab. Nat. Hist., 1872, p. 187.

Trematis truncata Hall, Twenty-third Rep. Ibidem, 1873, pl. 13, fig. 20.

Schizobolus truncatus Ulrich, Cont. American Pal., I, 1886, p. 25, pl. 3, fig. Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 87, pl. 3, figs. 11–14.

Loc. Ogdens Ferry, Cayuga Lake, etc., New York; Falls of Ohio; Madi County, Kentucky.

SCHIZOCRANIA Hall and Whitfield. Genotype Orbicula ? filosa H

Schizocrania Hall and Whitfield, Pal. Ohio, II, 1875, p. 71.—Hall and Clarke, New York, VIII, Pt. I, 1892, pp. 142, 168.—Winchell and Schuchert, Minnes Geol. Survey, III, 1893, p. 369.—Hall and Clarke, Eleventh Ann. Rep. N State Geologist, 1894, p. 259.

Digitized by Google

Schizocrania filosa Hall. Trenton-Lorraine (Ord.).

Orbicula? filosa Hall, Pal. New York, I, 1847, p. 99, pl. 30, fig. 9.

Trematis filosa Billings, Geol. Canada, 1863, p. 159, fig. 126.—Hall, Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, pl. 13, figs. 21, 22.

Trematis (?) filosa Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 15.

Schizocrania filosa Hall and Whitfield, Pal. Ohio, II, 1875, p. 73, pl. 1, figs. 12–15.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 143, pl. 4G, figs. 22–30.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 370, fig. 31; pl. 29, figs. 29–31.

Loc. Middleville, Utica, etc., New York; Ottawa, Canada; Cincinnati, Ohio; Cannon Falls and Minneapolis, Minnesota.

Schizocrania (?) helderbergia Hall. Lower Helderberg (Dev.).

Schizocrania (?) helderbergia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 144, 179, pl. 4G, figs. 34, 35.

Loc. Near Clarksville, New York.

Schizocrania (?) rudis Hall. Trenton (Ord.).

Trematis rudis Hall, Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, p. 243, pl. 13, fig. 19.

Schizocrania (?) rudis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 144, pl. 4G, fig. 21.

Loc. Clifton, Tennessee.

Schizocrania schucherti Hall and Clarke. Trenton (Ord.).

Schizocrania schucherti Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 143, 179, pl. 4G, figs. 31–33.

Loc. Covington, Kentucky.

Schizocrania superincreta Barrett. Lower Helderberg (Dev.).

Trematis (Schizocrania) superincreta Barrett, Annals N. Y. Acad. Sci., I, 1878, p. 122.

Schizocrania (?) superincreta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 144.

Loc. Port Jervis, New York.

SCHIZOPHORIA King. Genotype Orthis resupinata (Martin).

Schizophoria King, Mon. Permian Fossils, Pal. Soc., 1850, p. 106.—Hall, Bull. Geol. Soc. America, I, 1889, p. 21.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 211;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 272.

Schizophoria carinata Hall. Chemung (Dev.).

Orthis carinata Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 267, fig. 1;—Pal. New York, IV, 1867, p. 58, pl. 8, figs. 30–32;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, fig. 22.

Schizophoria carinata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 213, 226, pl. 6, fig. 22.

Loc. Painted Post, High Point, etc., New York.

Schizophoria cora (d'Orbigny). Upper Carboniferous.

Orthis cora d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 48.

Terebratula cora d'Orbigny, Ibidem, 1842, pl. 3, figs. 21–23.

Orthis resupinata var. latirostrata Toula, Sitzungsb. der k. k. Akad. der Wissensch. zu Wien, LIX, 1869, p. 8, pl. 1, fig. 7.—Derby, Bull. Cornell Univ., I, 1874, p. 63.

Loc. Yarbichambi and Cochabamba, Bolivia.

Schizophoria macfarlani (Meek). Middle and Upper Devonian.

Orthis macfarlani Meek, Trans. Chicago Acad. Sci., I, 1868, p. 88, pl. 12, fig. 1.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 423, pl. 13, fig. 10.—

Digitized by Google

Schizophoria macfarlani (Meek)—Continued.

Kayser, Richthofen's China, IV, 1883, p. 91, pl. 13, fig. 3.—Walcott, Mon Geol. Survey, VIII, 1884, p. 114.

Schizophoria macfarlanii Hall and Clarke, Pal. New York, VIII, Pt. I, 189 190, 212, 225, pl. 6A, figs. 28–32.

Loc. Independence, Iowa; Howard and High Point, New York; Mack River, Canada; Lower Devonian, Eureka district, Nevada; Southw China.

Schizophoria manitobaensis Whiteaves. Upper Devo

Orthis (Schizophoria) manitobensis Whiteaves, Cont. Canadian Pal., I, 18 283, pl. 37, figs. 3, 4, 5.

Loc. Lake Winnipegosis, Canada.

Schizophoria multistriata Hall. Lower Helderberg (D

Orthis multistriata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 45 1, 2;—Pal. New York, III, 1859, p. 176, pl. 15, fig. 2.

Schizophoria multistriata Hall and Clarke, Ibidem, VIII, Pt. I, 1892, pp 226, pl. 6A, fig. 25.

Loc. Schoharie and Catskill, New York.

Schizophoria (?) peduncularis Hall. Lower Helderberg (D

Orthis peduncularis Hall, Pal. New York, III, 1859, p. 174, pl. 13, fig. 16.

Schizophoria ? peduncularis Hall and Clarke, Pal. New York, VIII, Pt. I, p. 226.

Loc. Helderberg Mountains, New York.

Schizophoria propinqua Hall. Upper Helderberg (D

Orthis propinqua Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. Pal. New York, IV, 1867, p. 43, pl. 5, fig. 3;—Second Ann. Rep. N. Y. Geol., 1883, pl. 36, figs. 30, 31.

Schizophoria propinqua Hall and Clarke, Pal. New York, VIII, Pt. I, 189 212, 226, pl. 6, fig. 30.

Loc. New York; Columbus, Ohio.

Schizophoria resupinata (Martin). Carbonife

Orthis resupinata Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl 1877, p. 265, pl. 5, figs. 1, 2.

Schizophoria resupinata Hall and Clarke, Pal. New York, VIII, Pt. I, 189 194, 213, 226.

Loc. Oquirrh Mountains, Utah; Lake Valley mining district, New Mexico.

Schizophoria resupinoides (Cox). Upper Carbonife

Orthis resupinoides Cox, Owen's Geol. Survey Kentucky, II, 1857, p. 570, fig. 1.—Worthen, Geol. Survey Illinois, VIII, 1890, p. 106, pl. 11, fig. 4.

Orthis resupinoides? White, Wheeler's Expl. and Survey west 100th Meri Appendix, 1881, p. xxiii.

Schizophoria resupinoides Hall and Clarke, Pal. New York, VIII, Pt. I, pp. 213, 226.

Schizophoria cfr. resupinoides Smith, Proc. American Phil. Soc., XXXV, p. 28 (extract).

Loc. Hancock County, Kentucky; Manuelitos Creek, New Mexico; ?Whit Conway counties, Arkansas.

Obs. Probably identical with Schizophoria resupinata.

Schizophoria senecta Hall and Clarke. Clinton (

Orthis (Schizophoria) senecta Hall and Clarke, Pal. New York, VIII, Pt. I, p. 343, pl. 6A, figs. 23, 24.

Loc. Reynales Basin, Niagara County, New York.

Digitized by Google

Schizophoria striatula (Schlotheim). Middle and Upper Devonian.

Anomia Terebratulites striatulus Schlotheim, Min. Taschenbuch, VIII, 1813, pl. 1, fig. 6.

Orthis striatula Davidson, Brit. Devonian Brach., Pal. Soc., 1865, p. 87, pl. 17, figs. 4–7.—Whiteaves (non Schlotheim), Cont. Canadian Pal., I, 1891, pp. 218, 283.

Orthis impressa Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 267, fig. 2;—Pal. New York, IV, 1867, p. 60, pl. 8, figs. 11–19.—Whitfield, Geol. Wisconsin, IV, 1882, p. 326, pl. 25, figs. 13–15.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 115, pl. 13, fig. 13.—Kindle, Bull. American Pal., 6, 1896, p. 36.

Orthis lentiformis? Owen (non Hall), Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 3, figs. 10, 10a, young specimen. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17918.]

Orthis iowensis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 488, pl. 2, fig. 4.—Billings, Hind's Rep. Expl. Assiniboine and Saskatch., 1859, p. 187, fig. 1.—Meek, Trans. Chicago Acad. Sci., I, 1868, p. 90, pl. 12, fig. 2.—White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, p. 501, pl. 5, figs. 10–12;—Tenth Rep. State Geol. Indiana, 1881, p. 133, pl. 5, figs. 10–12.—Keyes, Geol. Survey Missouri, V, 1895, p. 62, pl. 38, fig. 6.

Orthis iowensis var. furnarius Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 489, pl. 2, fig. 5.—Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 424, pl. 13, fig. 9.

?Orthis iowensis ? A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 410.

Orthis propinqua Nettelroth (non Hall), Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 43, pl. 16, figs. 1–3, 7–11.

Schizophoria iowensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 212, 226, pl. 6A, fig. 29.

Schizophoria impressa Hall and Clarke, Ibidem; 1892, pp. 212, 216, pl. 6, fig. 31; pl. 6A, figs. 26, 27.

Loc. New York; Falls of Ohio; Illinois; Iowa; Milwaukee, Wisconsin; Perry County, Missouri; Eureka district, Nevada; Mackenzie River Valley, Northwest Territory, Canada.

Obs. The writer has compared American forms with O. striatula from the Eifel, Germany, and he agrees with authors in regarding both as one species. Orthis (Schizophoria) macfarlani is often found associated with O. striatula and may be only a variety of it.

Schizophoria swallovi Hall. Burlington (L. Carb.).

Orthis swallovi Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 597, pl. 12, fig. 5;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, figs. 23, 24.—Keyes, Geol. Survey Missouri, V, 1895, p. 63, pl. 38, fig. 5.

Schizophoria swallovi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 213, 226, pl. 6, figs. 23, 24.

Loc. Burlington, Iowa; Quincy, Illinois; Pike County, Missouri.

Obs. Compare with Rhipidomella clarkensis.

Schizophoria tioga Hall. Portage and Chemung (Dev.).

Orthis interlineata Hall (non Sowerby), Geol. N. Y.; Rep. Fourth Dist., 1843, p. 267, figs. 3, 4.

Orthis tioga Hall, Pal. New York, IV, 1867, p. 59, pl. 8, figs. 20–29;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 36, figs. 17, 18.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 561, pl. 12, fig. 3;—Geol. Ohio, VII, 1895, p. 453, pl. 8, fig. 3.

Schizophoria tioga Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 212, 226, pl. 6, figs. 17, 18.

Loc. Factoryville, Elmira, etc., New York; Lake County, Ohio.

Digitized by Google

Schizophoria tulliensis (Vanuxem). Tully (D

Orthis tulliensis Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 164, fig.
Hall, Pal. New York, IV, 1867, p. 55, pl. 7, fig. 5.—Walcott, Mon.
Geol. Survey, VIII, 1884, p. 115, pl. 2, fig. 12.—Williams, Bull. Geol.
America, I, 1890, p. 492, pl. 12, fig. 16.

Orthis resupinata Hall (non Martin), Geol. N. Y.; Rep. Fourth Dist., 1843, p
fig. 2.

Orthis (Schizophoria) tulliensis Hall, Second Ann. Rep. N. Y. State Geol.,
pl. 36, figs. 25–29.

Schizophoria tulliensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892
212, 226, pl. 6, figs. 25–29.

Loc. Tully, Tinkers Falls, and Ovid, New York; Eureka district, Nevada.

SCHIZOTRETA Kutorga. Genotype S. elliptica Kuto

Schizotreta Kutorga, Verhand. Kais. Min. Gessel. zu St. Petersburg, VII,
p. 273.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 135, 1
Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 365.—Hal
Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 257.

Schizotreta conica (Dwight). Trenton (O

Orbiculoidea conica Dwight, American Jour. Sci., 3d ser., XIX, 1880, p. 45
21, figs. 1–11.

Schizotreta conica Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp
135, pl. 4E, figs. 6–8; pl. 4F, fig. 7.

Loc. Near Newburg, New York.

Schizotreta minutula Winchell and Schuchert. Lorraine (O

Schizotreta minutula Winchell and Schuchert, Minnesota Geol. Survey, III,
p. 366, fig. 28.

Loc. Near Granger, Minnesota.

Schizotreta ovalis Hall and Clarke. Trenton (O

Orbiculoidea (Schizotreta) ovalis Hall and Clarke, Pal. New York, VIII,
1892, p. 177, pl. 4E, figs. 4, 5.

Loc. Middleville, New York.

Schizotreta pelopea (Billings). Trenton and Lorraine (O

Discina pelopea Billings, Pal. Fossils, I, 1862, p. 52, fig. 56;—Geol. Canada,
p. 159, fig. 124.

Discina concordensis Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p.
pl. 4, figs. 13, 14.

Schizotreta pelopea, Winchell and Schuchert, Minnesota Geol. Survey, III,
p. 365, pl. 29, figs. 26–28.

Loc. Montreal, Canada; Mantorville, Old Concord, and Spring Valley, Mi
sota; Dubuque, Iowa; Neenah, Wisconsin; in the Utica at Ottawa, Ca
(Ami).

Schizotreta tenuilamellata (Hall). Niagara (S

Orbicula tenuilamellata Hall, Pal. New York, II, 1852, p. 250, pl. 53, fig. 3.

Discina forbesi Nicholson (non Davidson), Pal. Prov. Ontario, 1875, p. 62.

Discina solitaria Ringueberg, American Naturalist, 1882, p. 175, figs. a–e.

Discina clara Spencer, Bull. Univ. State Missouri, 1, 1884, p. 56;—Trans
Louis Acad Sci., IV, 1886, p. 606, pl. 8, fig. 5.

Schizotreta tenuilamellata Beecher, American Jour. Sci., 3d ser., XLI, 189
357, pl. 17, fig. 11.

Orbiculoidea (Schizotreta?) tenuilamellata Hall and Clarke, Pal. New Y
VIII, Pt. I, 1892, pp. 127, 135, pl. 4E, figs. 9–11; pl. 4F, figs. 2–6.

Loc. Lockport, New York; Hamilton, Ontario, and Arisaig, Nova Scotia (A

Digitized by Google

SELENELLA Hall and Clarke. Genotype S. gracilis Hall and Clarke.

Selenella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 271;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 855.

Selenella gracilis Hall and Clarke. Corniferous (Dev.).

Selenella gracilis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 271, figs. 184–186.

Loc. Ontario.

SEMINULA McCoy emend Hall and Clarke.

Genotype Terebratula pentædra Phillips=Athyris ambigua (Phillips).

Seminula McCoy, Synopsis Carb. Fossils Ireland, 1844, pp. 150, 158.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 93;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 781.

Seminula argentea (Shepard). Upper Carboniferous.

Terebratula argentea Shepard, American Jour. Sci., XXXIV, 1838, p. 152, fig. 8.

Terebratula roissyi d'Orbigny (non L'Éveillé), Voyage dans l'Amérique Méridionale, Pal., 1842, p. 46.

Terebratula antisiensis d'Orbigny, Ibidem, 1842, p. 46 (non p. 36).

Terebratula peruviana d'Orbigny, Ibidem, 1842, pl. 3, figs. 17–19 (non p. 36).

Terebratula subtilita Hall, Stansbury's Exped. Great Salt Lake of Utah, 1852, p. 409, pl. 4, figs. 1, 2.—Shumard, Marcy's Rep. U. S. Expl. Red River of Louisiana, 1853, p. 202, pl. 4, fig. 8.—Schiel, Pacific Railroad Rep., II, 1855, p. 108, pl. 1, fig. 2.—Hall, Ibidem, III, 1856, p. 101, pl. 2, figs. 3–5.—Marcou, Geol. N. America, 1858, p. 52, pl. 6, fig. 9.—Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 714.

Terebratula (?) subtilita Davidson, Mon. British Carboniferous Brach., Pal. Soc., 1857, p. 18, pl. 1, figs. 21, 22; 1860, p. 86; 1862, p. 217, pl. 17, figs. 8–10.

Spirigera subtilita Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p. 20.—White, Wheeler's Expl. and Survey west of the 100th Meridian, IV, 1875, p. 141, pl. 10, fig. 6.

Athyris differentis McChesney, New Pal. Fossils, 1860, p. 47.

Athyris subtilita Newberry, Ives's Rep. Colorado River of the West, 1861, p. 126.—Salter, Quart. Jour. Geol. Soc. London, XVII, 1861, p. 64, pl. 4, fig. 4.—Geinitz, Carbon und Dyas in Nebraska, 1866, p. 40, pl. 3, figs. 7–9.—Meek, Final Rep. U. S. Geol. Survey, Nebraska, 1872, p. 180, pl. 1, fig. 12; pl. 5, fig. 9; pl. 8, fig. 4.—Meek and Worthen, Geol. Survey Illinois, V, 1873, p. 570, pl. 25, fig. 14.—Derby, Bull. Cornell Univ., I, 1874, p. 7, pl. 1, figs. 5, 8 (not 7=Spirigerella derbyi); pl. 3, figs. 8, 16, 19; pl. 6, fig. 2; pl. 9, fig. 4.—Meek, Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p. 350, pl. 2, fig. 4;—Bull. U. S. Geol. and Geogr. Survey Terr., II, 4, 1876, pl. 1, fig. 2.—Derby, Bull. Mus. Comp. Zool., III, 1876, p. 279.—Newberry, Macomb's Rep. Expl. Exped. from Santa Fe to the Great Colorado River of the West, 1876, p. 138.—Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 83, pl. 8, fig. 6.—White, Thirteenth Rep. State Geol. Indiana, 1884, p. 136, pl. 35, figs. 6–9.—de Koninck, Annales du Musée Royal d'Histoire Naturelle de Belgique, XIV, 1887, p. 73, pl. 18, figs. 1–4, 7–10, 12–28; pl. 19, figs. 47–56.—Herrick, Bull. Denison Univ., II, 1887, p. 44, pl. 2, fig. 23.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1888, p. 231.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 604, pl. 16, figs. 7–9;—Geol. Ohio, VII, 1895, p. 488, pl. 12, figs. 7–9.

Spirifera (Athyris) subtilita Toula, Sitzungsb. der k. k. Akad. der Wissensch. zu Wien, LIX, 1869, p. 6, pl. 1, fig. 5.

Seminula subtilita Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 95, figs. 66, 67, and 58, 59 on p. 86; pl. 47, figs. 17–31.

Athyris argentea Keyes, Geol. Survey Missouri, V, 1895, p. 92, pl. 39, fig. 11.

Loc. Throughout the Upper Carboniferous of North America; Brazil and Bolivia, South America; England; India; Thibet and Kashmere.

Obs. See Seminula charitonensis, S. caput-serpentis, S. hawni, and S. singletonii Swallow.

Digitized by Google

Seminula caput-serpentis (Swallow). Upper Carbonif

Spirigera caputserpentis Swallow, Trans. St. Louis Acad. Sci., II, 1863,

Loc. Missouri and Kansas.

Obs. Regarded by Keyes as a synonym for S. argentea.

Seminula charitonensis (Swallow). Upper Carbonif

Spirigera charitonensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p.

Loc. Chariton and Randolph counties, Missouri.

Obs. Probably a synonym for Seminula argentea.

Seminula claytoni (Hall and Whitfield). Kinderhook (L.

Athyris claytoni Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV 1877, pl. 4, figs. 15–17.

Loc. Little Cottonwood, Wasatch Range, Utah.

Seminula dawsoni Hall and Clarke. Upper Carbonif

Athyris subtilita Davidson (non Hall), Quart. Jour. Geol. Soc. Londor 1863, p. 170, pl. 9, figs. 4, 5.—Dawson, Acadian Geology, 3d ed., 1878, fig. 88.

Seminula dawsoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp 364, figs. 69–71; pl. 47, figs. 32–34.

Loc. Windsor, Nova Scotia.

Seminula formosa (Swallow). Keokuk (L.

Spirigera formosa and euzona Swallow, Trans. St. Louis Acad. Sci., II, 186

Athyris formosa Keyes, Geol. Survey Missouri, V, 1895, p. 91.

Loc. Boonville, Missouri.

Seminula hawni (Swallow). Upper Carbonif

Spirigera hawni Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 652.

Loc. Missouri.

Obs. Probably a synonym for Seminula argentea.

Seminula maconensis (Swallow). Upper Carbonif

Spirigera maconensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 651

Loc. Montgomery County, Missouri.

Seminula parva (Swallow). Keokuk (L.

Terebratula parva Swallow (non d'Archiac, 1846), Trans. St. Louis Aca II, 1863, p. 83.—Keyes, Geol. Survey Missouri, V, 1895, p. 105.

Terebratula cooperensis Miller, N. American Geol. and Pal., 1889, p. 384.

Loc. Keokuk, Iowa; Monroe and Cooper counties, Missouri.

Obs. Specimens of this species in Professor Hall's collection seen by the do not show a punctate shell structure, but are distinctly fibrous.

Seminula persinuata (Meek). Carbonif

Athyris (?) persinuata Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877 pl. 9, fig. 4.

Loc. White Pine district, Nevada.

Seminula (?) plattensis (Swallow). Upper Carbonif

Spirigera plattensis Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 87.

Loc. Missouri; Kansas; Nebraska.

Seminula (?) rogersi Hall and Clarke. Upper Helderberg (

Seminula rogersi Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pp. pl. 47, figs. 1–4.

Loc. Pendleton, Indiana.

Seminula singletonii (Swallow). Upper Carbonif

Spirigera singletonii Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 87.

Loc. Boone and Audrain counties, Missouri.

Obs. Probably a synonym for Seminula argentea.

Digitized by Google

Seminula subquadrata Hall. Kaskaskia (L. Carb.).

Athyris subquadrata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 703, pl. 27, fig. 2, woodcut p. 708.—Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 585, pl. 14, figs. 1–3;—Geol. Ohio, VII, 1895, p. 472, pl. 10, figs. 1–3.—Keyes, Geol. Survey Missouri, V, 1895, p. 92.

Athyris subquadrata? Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 271, pl. 5, figs. 19, 20.

Seminula subquadrata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 95, pl. 47, figs. 7–9, 15, 16; pl. 84, figs. 30, 31.

Loc. Chester, Illinois; Crittenden County, Kentucky; Newtonville and Maxville, Ohio; Oquirrh Mountains, Utah.

Obs. See Cleiothyris clintonensis.

Seminula titicacaensis (Gabb). Upper Carboniferous.

Terebratula titicacensis Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., VIII, 1881, p. 302, pl. 42, fig. 11.

Loc. Lake Titicaca, Bolivia.

Seminula trinucleus Hall. St. Louis (L. Carb.).

Terebratula trinucleus Hall, Trans. Albany Institute, IV, 1858, p. 7;—Geol. Survey Iowa, I, Pt. II, 1858, p. 659, pl. 23, figs. 4, 5.

Athyris trinuclea Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 50, pl. 6, figs. 22–27.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 329, pl. 29, figs. 22–27.

Seminula trinuclea Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 94, 95, fig. 65; pl. 47, figs. 5, 6, 10–14.

Loc. Bloomington and Spergen Hill, Indiana; Alton, Illinois; Boonville, Missouri; Princeton, Kentucky.

Obs. See Cleiothyris reflexa.

Seminula wasatchensis (White). Upper Carboniferous.

Rhynchonella wasatchensis White, Wheeler's Expl. and Survey west of 100th Meridian, Prel. Rep. 1874, p. 19;—Ibidem, Final Rep., 1875, p. 130, pl. 9, fig. 3.

Loc. Wasatch Range, near Provo, Utah.

Obs. Is related to S. subtilita. The great anterior thickening is due to old age.

Sieberella Œhlert, and Hall and Clarke=Gypidula.

Obs. It may prove that Sieberella will be useful as a subgenus of Gypidula.

SIPHONOTRETA de Vern. Genotype Crania unguiculata Eichwald.

Siphonotreta de Verneuil, Géol. de la Russie d'Europe et des Mont. de l'Oural, II, 1845, p. 286.—Dall, Bull. U. S. Nat. Mus., 8, 1877, p. 62.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 110, 167.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 358.—Hall and Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 252.

Siphonotreta (?) micula McCoy. Calciferous (Ord.).

Siphonotreta? micula Ami, Rep. Progress Geol. Nat. Hist. Survey Canada for 1887–88, 1889, p. 52K.

Loc. Great Britain; near Laevis, Canada.

Siphonotreta (?) minnesotaensis Hall and Clarke. Trenton (Ord.).

Siphonotreta? minnesotensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 112, 177, pl. 4, figs. 37, 38.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 358, pl. 29, figs. 23, 24.

Loc. Minneapolis, Minnesota.

Siphonotreta scotica Whiteaves=Schizambon? fissus americanus.

SPHÆROBOLUS Matthew. Genotype Lingulella? spissa Billings.

Sphærobolus Matthew, Trans. Royal Soc. Canada, 2d ser., I, 1896, p. 263.

Digitized by Google

Sphærobolus spissus (Billings). Lower Ord

Lingulella ? spissa Billings, Canadian Nat. Geol., n. ser., VI, 1872, p. 5;—Pal. Fossils, II, 1874, p. 67, fig. 36.

Sphærobolus spissus Matthew, Trans. Royal Soc. Canada, 2d ser., I, 263, pl. 1, fig. 5.

Loc. Bell Island, Newfoundland.

SPIRIFER Sowerby. Genotype Anomites striatus

Spirifer Sowerby, Mineral Conchology, II, 1815, p. 41.—Billings, Canad Geol., I, 1856, p. 134.—Meek and Hayden, Pal. Upper Missouri, Smi Cont. to Knowledge, XIV, 172, 1864, p. 17.—Hall and Clarke, Pal. N VIII, Pt. II, 1893, pp. 1–40;—Thirteenth Ann. Rep. N. Y. State G 1895, p. 751.

Spirifera Billings, Canadian Journal, VI, 1861, p. 253.—Hall, Twentiet Y. State Cab. Nat. Hist., 1867, p. 251;—Pal. New York, IV, 1867, White, Wheeler's Expl. and Survey west of the 100th Merid., 1875 Herrick, Bull. Denison University, IV, 1888, p. 14.—Nettelroth, K Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 105.—Hall, B Soc. America, I, 1890, p. 567;—Ninth Ann. Rep. N. Y. State Geol., 1

Spirifer acanthopterus (Conrad). ? Hamilton

Delthyris acanthoptera Conrad, Jour. Acad. Nat. Sci. Philadelphia, V p. 264.

Loc. Oneonta, Otsego County, New York.

Spirifer acuminatus (Conrad). Corniferous and Hamilton

Delthyris acuminata Conrad, Third Ann. Rep. N. Y. Geol. Survey, 1839

Delthyris prora Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842,

Terebratula acuminatissima Castelnau, Essai Syst. Silurien l'Amériqu trionale, 1843, p. 40, pl. 14, fig. 16.

Spirifer cultrijugatus Yandell and Shumard (non Roemer, 1844), Cont. G tucky, 1847, p. 10.

Spirifer acuminata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857,

Spirifera acuminata Hall, Pal. New York, IV, 1867, pp. 198, 234, pl. 9–18; pl. 35, fig. 24.—Nettelroth, Kentucky Fossil Shells, Mem. K Geol. Survey, 1889, p. 105, pl. 8, figs. 1–8.

Spirifer acuminatus White, Second Rep. Indiana Bureau of Statistics a 1880, p. 503, pl. 4, figs. 1–3;—Tenth Rep. State Geol. Indiana, 188 pl. 4, figs. 1–3.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p pl. 39, figs. 39–42.

Loc. Schoharie, Williamsville, Clarence Hollow, Hamilton, Madison, York; Columbus and Sandusky, Ohio; Falls of Ohio.

Spirifer acuticostatus de Koninck. Upper Carbon

Spirifer acuticostatus de Koninck, Animaux Fos. Carb. Belgique, p. 2 fig. 6.

Spirifera acuticostata Davidson, Quart. Jour. Geol. Soc. London, XIX 171, pl. 9, figs. 7, 8.—Dawson, Acadian Geol., 3d ed., 1878, p. 292, fi

Loc. Europe; Brookfield and Shubenacadie, Nova Scotia.

Spirifer agelaius Meek. Lower Carbon

Spirifer triradialis? Meek (non Phillips), Sixth Ann. Rep. U. S. Geol Terr., 1873, p. 470.

Spirifer agelaius Meek, Ibidem, 1873, p. 470, footnote.—White, Twel Rep. U. S. Geol. Survey Terr., 1883, p. 135, pl. 34, fig. 10.

Loc. Near Virginia City, Montana.

Spirifer alatus Castelnau (non Schlotheim)=**Spirifer aliformis.**

Digitized by Google

Spirifer aliformis de Verneuil. Upper Helderberg (Dev.).
Spirifer alatus Castelnau (non Schlotheim), Essai Système Silurien l'Amérique Septentrionale, 1843, p. 42, pl. 12, fig. 4.
Spirifer alæformis de Verneuil, Ibidem, 1843, p. 42, footnote.
Loc. Schoharie, New York.
Obs. Compare with Spirifer arenosus.

Spirifer alba-pinensis Hall and Whitfield. Kinderhook (L. Carb.).
Spirifera albapinensis Hall and Whitfield, King's U. S. Geol. Expl., 40th Parl., IV, 1877, p. 255, pl. 4, figs. 7, 8.
Loc. Wasatch Range, Utah.
Obs. Appears to be a synonym of S. centronatus.

Spirifer aldrichi Etheridge. Devonian.
Spirifer aldrichi Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 634, pl. 29, fig. 2.
Loc. Dana Bay, lat. 82° 42′.

Spirifer alta Hall=Cyrtia alta.

Spirifer amarus Swallow. Hamilton (Dev.).
Spirifer amarus Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 642.
Loc. On page 658 it is given as Callaway County, Missouri, in association with Hamilton terrane fossils. It is probably the same as S. annæ Swallow.

Spirifer angustus Hall. Hamilton and Portage (Dev.).
Spirifer angusta Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 164, fig. in text.
Spirifera angusta Hall, Pal. New York, IV, 1867, p. 230, pl. 38A, figs. 23–32.—Whitfield, Geol. Wisconsin, IV, 1882, p. 329, pl. 26, fig. 3.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 54, figs. 14–17.
Spirifer angustus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 31, 39, pl. 24, figs. 14–17.
Loc. Livingston and Genesee counties, and Ithaca, New York; Portage group of New York (Williams); Milwaukee, Wisconsin.

Spirifer annæ Swallow. Hamilton (Dev.).
Spirifer annæ Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 641.
Loc. Callaway County, Missouri.
Obs. See S. amarus.

Spirifer annectans Walcott. Lower Carboniferous.
Spirifera annectans Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 216, pl. 18, fig. 7.
Loc. Eureka district, Nevada.

Spirifer antarcticus Morris and Sharpe. Lower Devonian.
Spirifer antarcticus Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 276, pl. 11, fig. 2.
Loc. Falkland Islands.
Obs. Compare with S. boliviaensis, S. chuquisaca, and S. orbignyi.

Spirifer arata Hall=Spirifer granulosus.

Spirifer arcticus Houghton. Devonian.
Spirifer arcticus Houghton, Jour. Royal Dublin Soc., I, 1857, p. 183.
Obs. The writer has not seen this journal.

Spirifer arctisegmentum Hall. Upper Helderberg (Dev.).
Spirifer arctisegmenta Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 131.
Spirifera arctisegmenta Hall, Pal. New York, IV, 1867, p. 208, pl. 31, figs. 9, 10;—

Digitized by Google

Spirifer arctisegmentum Hall—Continued.

Second Ann. Rep. N. Y. State Geol., 1883, pl. 59, figs. 10–12.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 108, pl. 12, figs. 14, 15.

Spirifer arctisegmentus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 36, pl. 34, figs. 10–12.

Loc. Stafford and Genesee counties, New York; Falls of Ohio.

Spirifer arenosus (Conrad). Oriskany and Corniferous (Dev.).

Delthyris arenosa Conrad, Third Ann. Rep. N. Y. Geol. Survey, 1839, p. 65.—Mather, Geol. N. Y.; Rep. First Dist., 1843, p. 342, fig. 1.—Hall, Ibidem, Rep. Fourth Dist., 1843, p. 148, fig. 1.

Delthyris arenaria Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 123, fig. 1; p. 124, fig. 5.

Spirifer arenosa Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 826, fig. 650.—Hall, Pal. New York, III, 1859, p. 425, pl. 98, figs. 1–8; pl. 99, figs. 1–10; pl. 100, figs. 1–8.

Spirifera arenosa Billings, Geol. Canada, 1863, p. 960, fig. 465.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, figs. 3–7.

Spirifera unica Hall, Pal. New York, IV, 1867, p. 203, pl. 30, fig. 21; pl. 55, fig. 8.

Spirifer arenosus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 24, 27, 37, pl. 29, figs. 1–4; pl. 30, figs. 3–8.

Loc. Schoharie, Clarence Hollow, etc., New York; Cumberland, Maryland; Virginia; Frankstown, Pennsylvania; Cayuga, Ontario.

Spirifer argentarius Meek=Spirifer pinonensis.

Spirifer arrectus Hall=Spirifer murchisoni.

Spirifer asper Hall. Hamilton (Dev.).

Spirifer aspera Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 508, pl. 4, fig. 7.

Spirifera (Cyrtina) aspera Whitfield, Geol. Wisconsin, IV, 1882, p. 331, pl. 26, figs. 1, 2.

Spirifer asper Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 29, 31, 32, 39, pl. 25, figs. 20–25.

Loc. Independence and Rockford, Iowa; Rock Island, Illinois; Milwaukee, Wisconsin; Canandaigua, New York.

Spirifer asperatus Ringueberg. Niagara (Sil.).

Spirifera asperata Ringueberg, Bull. Buffalo Soc. Nat. Sci., V, 1886, p. 16, pl. 2, fig. 5.

Loc. Lockport, New York.

Spirifer atwateranus Miller=Spirifer iowaensis.

Spirifer audaculus (Conrad). Marcellus and Hamilton (Dev.).

Delthyris audacula Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 262.

Delthyris medialis Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 208, fig. 8.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 828, fig. 669.

Spirifer eatoni Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 157.

Spirifer medialis Hall, Ibidem, 1857, p. 164, fig. 1.

Spirifera medialis Hall, Pal. New York, IV, 1867, p. 227, pl. 38, figs. 1–25,—Second Ann. Rep. N. Y. State Geol., 1883, pl. 54, figs. 1–13.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 125, pl. 26, figs. 2–5.

Spirifera medialis var. eatoni Hall, Pal. New York, IV, 1867, pl. 38, figs. 12–18.

Spirifera audacula Whitfield, Geol. Wisconsin, IV, 1882, p. 329, pl. 25, figs. 25, 26.

Spirifer audaculus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 29–31, 39, pl. 24, figs. 1–13; pl. 29, fig. 5.

Loc. Otsego, Cayuga, Moscow, Darien, etc., New York; Falls of Ohio; Milwaukee, Wisconsin.

Digitized by Google

Spirifer audaculus macronotus Hall. Hamilton (Dev.).

Delthyris macronota Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 206, fig. 5.

Spirifera macronota Hall, Pal. New York, IV, 1867, p. 231, pl. 38A, figs. 1–22;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 54, figs. 18–27.

Spirifer audaculus var. macronotus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 24, figs. 18–27.

Loc. Bristol, Moscow, Darien, etc., New York.

Spirifer buarquianus Rathbun. Middle Devonian.

Spirifera buarquiana Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 28.

Loc. Rio Maecuru, Province of Para, Brazil.

Spirifer belphegor Clarke. Genesee (Dev.).

Spirifera belphegor Clarke, Bull. U. S. Geol. Survey, 16, 1885, p. 30, pl. 3, fig. 13.

Loc. Ontario County, New York.

Spirifer bicostatus Hall=Reticulara bicostata.

Spirifer bicostatus var. petilus Hall=Reticularia bicostata petila.

Spirifer bidorsalis Winchell. Hamilton (Dev.).

Spirifera bidorsalis A. Winchell, Geol. Rep. Lower Peninsula of Michigan, 1866, p. 93.

Loc. Grand Traverse district, Michigan.

Spirifer biforatus var. lynx Hall=Platystrophia biforata.

Spirifer bifurcatus Hall=Spirifer leidyi.

Spirifer billingsanus Miller. Oriskany (Dev.).

Spirifera superba Billings (non Eichwald), Pal. Fossils, II, 1874, p. 45, pl. 3A, fig. 3.

Spirifera billingsana Miller, N. American Geol. Pal., 1889, p. 372.

Loc. Indian Cove, Gaspé.

Spirifer bilobus Hall=Bilobites bilobus.

Spirifer bimesialis Hall. Upper Devonian.

Spirifer bimesialis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 507, pl. 4, fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 17, 36, pl. 34, figs. 23–26.

Spirifera bimesialis Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 59, figs. 23–26.

Loc. Independence, Iowa; Naples, New York (Clarke).

Spirifer biplicatus Meek (non Hall)=Spirifer centronatus.

Spirifer biplicatus Hall. Kinderhook (L. Carb.).

Spirifer biplicata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 519, pl. 7, fig. 5.

Spirifera biplicata Herrick, Bull. Denison Univ., III, 1888, p. 45; IV, 1888, p. 25, pl. 2, fig. 8.

Spirifer biplicatus Herrick, Geol. Ohio, VII, 1895, pl. 15, fig. 8.

Loc. Burlington, Iowa; Quincy, Illinois; Richfield, etc., Ohio.

Spirifer boliviaensis d'Orbigny. Devonian.

Spirifer boliviensis d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 37, pl. 2, figs. 8, 9.

Loc. Cochabamba and Chuquisaca, Bolivia.

Obs. Compare with S. antarcticus and S. hawkinsi.

Spirifer boonensis Swallow. Upper Carboniferous.

Spirifer boonensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 646.

Loc. Boone, Randolph, and Monroe counties, Missouri.

Obs. Regarded by Keyes as a synonym for S. rockymontanus.

Digitized by Google

Spirifer byrnesi Nettelroth. Hamilt

Spirifera byrnesi Nettelroth, Kentucky Fossil Shells, Mem. Kentuck vey, 1889, p. 109, pl. 10, figs. 1–5?, 31–34, 36–39.

Loc. Falls of Ohio.

Spirifer cameratus Derby (non Morton)=Spirifer condor.

Spirifer cameratus Morton. Upper Carb

Spirifer cameratus Morton, American Jour. Sci., XXIX, 1836, p. 150, p Hall, Pacific Railroad Reports, III, 1856, p. 102, pl. 2, figs. 9, Survey Iowa, I, Pt. II, 1858, p. 709, pl. 28, fig. 2.—Geinitz, Carbo in Nebraska, 1866, p. 44.—Meek, Final Rep. U. S. Geol. Survey 1872, p. 183, pl. 6, fig. 12; pl. 8, fig. 15.—Meek and Worthen, G Illinois, V, 1873, p. 573, pl. 25, fig. 7.—Toula, Neues Jahrbuch 1874, p. 240;—Sitzungsb. der Kais. Akad. der Wissen. zu Wie 543.—White, Wheeler's Expl. Survey west 100th Meridian, IV, pl. 10, fig. 1.—Newberry, Macomb's Rep. Expl. Exped. from Sant Great Colorado River of the West, 1876, p. 138.—Meek, Simpson's Great Basin Terr. Utah, 1876, p. 353, pl. 2, fig. 3.—Hall and C New York, VIII, Pt. II, 1893, pp. 26, 38, pl. 32, figs. 9–15.

Spirifer meusebachanus Roemer, Kreidebildung Texas, 1852, p. 88, p

Spirifer triplicatus Hall, Stansbury's Expl. Survey of the Valley of Lake, Utah, 1852, p. 410, pl. 4, fig. 5.

Spirifer inequicostatus? Owen, Geol. Survey Wisconsin, Iowa, and 1852, p. 586, pl. 5, fig. 6. [See specimens in U. S. Nat. Mus., Cat. In 17954.]

Spirifer fasiger Owen (non Keyserling), Ibidem, 1852, pl. 5, fig. 4.

Spirifer striatus var. triplicatus Marcou, Geol. N. America, 1858, p fig. 3.

Spirifer species Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 833, fi

Spirifer camerata Meek and Hayden, Proc. Acad. Nat. Sci. Philade p. 27.

Spirifera camerata Newberry, Ives's Rep. Colorado River of the We 127.—White, Second Ann. Rep. Indiana Bureau Statistics and p. 517, pl. 8, fig. 3;—Tenth Rep. State Geol. Indiana, 1881, p. fig. 3.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 57, f White, Thirteenth Rep. State Geol. Indiana, 1884, p. 132, pl. 35, Herrick, Bull. Denison Univ., II, 1887, p. 45, pl. 2, fig. 22.—K Acad. Nat. Sci. Philadelphia, 1888, p. 230;—Geol. Survey Missou p. 83, pl. 40, fig. 5.

Spirifera camerata var. kansasensis Swallow, Trans. St Louis Aca 1867, p. 409.

Spirifer (Trigonotreta) camerata Meek, King's U. S. Geol. Expl. 40th 1877, p. 91, pl. 9, fig. 2.

Loc. Putnam Hill, Ohio; throughout the Upper Carboniferous of N ica; western side of Spitzbergen (Toula).

Obs. S. cameratus is often regarded as identical with S. striatus (Ma latter species, however, is closely and finely reticulated with growth lines, while in S. cameratus the plications are crowded pustules arranged in radiating lines. See S. condor and S. striat

Spirifer cameratus var. kansasensis Swallow=Spirifer camera

Spirifer cameratus percrassus Swallow. Upper Carbo

Spirifer cameratus var. percrassus Swallow, Trans. St. Louis Acad. Sc p. 409.

Loc. Missouri and Kansas.

Obs. Regarded by Keyes as a synonym for S. cameratus.

Digitized by Google

Spirifer capax Hall=Spirifer euryteines.
Spirifer canandaiguæ Hall and Clarke=Reticularia canandaiguæ.
Spirifer carteri Hall=Syringothyris carteri.
Spirifer carteri Meek (non Hall)=Syringothyris texta.
Spirifer catskillensis Emmons=Spirifer mesistrialis.
Spirifer cedarensis Owen=S. iowaensis.

Spirifer centronatus A. Winchell. Waverly (L. Carb.).

Spirifer centronatus A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 118.—White, Wheeler's Expl. Survey west 100th Merid., IV, 1875, p. 86, pl. 5, fig. 8.

Spirifera (Trigonotreta) biplicata (Hall??) Meek, Pal. Ohio, II, 1875, p. 290, pl. 14, fig. 5.

Spirifera centronata Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 254, pl. 4, figs. 5, 6.

Loc. Cuyahoga Falls, Ohio; Black Hills, South Dakota; Wasatch Range, Utah; Mountain Spring, Nevada; Yellowstone Park.

Obs. See S. alba-pinensis.

Spirifer chilensis Forbes=Spiriferina rostrata.

Spirifer chuquisaca A. Ulrich. Middle Devonian.

Spirifer chuquisaca A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 65, pl. 4, figs. 19, 20.

Loc. Chahuarani, Tarabuco, etc., Bolivia.

Obs. Compare with S. boliviaensis and S. antarcticus.

Spirifer clarus Swallow=Reticularia clara.

Spirifer clavatulus McChesney. Burlington (L. Carb.).

Spirifera clavatula McChesney, New Pal. Fossils, 1861, p. 84;—Trans. Chicago Acad. Sci., I, 1868, p. 36, pl. 6, fig. 5.

Loc. Burlington, Iowa.

Spirifer clintoni Hall=Spirifer granulosus.
Spirifer clio Hall=Delthyris consobrina.
Spirifer compactus Meek=Reticularia fimbriata.

Spirifer concinnus Hall. Lower Helderberg (Dev.).

Spirifer concinna Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 60, figs. 1-3.

Spirifera concinna Hall, Pal. New York, III, 1859, p. 200, pl. 25, fig. 2; pl. 28, fig. 7;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, figs. 1, 2.

Spirifer concinnus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 24, 27, 38, pl. 30, figs. 1, 2.

Loc. Helderberg Mountains, New York.

Spirifer condor d'Orbigny. Upper Carboniferous.

Spirifer condor d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 46, pl. 5, figs. 11-14.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 514.

Spirifer striatus var. multicostatus Toula, Sitzungsb. der kais. Akad. der Wissensch. zu Wien, 1869, p. 3, pl. 1, figs. 2-4.

Spirifera camerata Derby (non Morton), Bull. Cornell Univ., I, 1874, p. 12, pls. 1, 2, 4, 5;—Bull. Mus. Comp. Zool., III, 1875, p. 279.

Loc. Bolivia; Bomjardim and Itaituba, Brazil; Yampopata and the Island of Titicaca, Bolivia; Pichis River, Peru.

Digitized by Google

Spirifer condor d'Orbigny—Continued.

Obs. "It has for a long time been considered a synonym of S. striatus and later of S. cameratus. It is distinct, however, from the former by the lamellose striæ of growth and from the latter by these as well by the nearly entire absence of bundling of the ribs" (Waagen).

Spirifer conradanus Miller=Reticularia fimbriata.

Spirifer consobrina d'Orbigny=Delthyris consobrina.

Spirifer consors A. Winchell. Hamilton (Dev.).

Spirifer consors A. Winchell, Geol. Rep. Lower Peninsula of Michigan, 1866, p. 93.

Loc. Grand Traverse district, Michigan.

Spirifer cooperensis Waagen=Reticularia cooperensis.

Spirifer corticosus Hall. Hamilton (Dev.).

Spirifer corticosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 160.

Spirifera corticosa Hall, Pal. New York, IV, 1867, p. 236.

Loc. Cumberland, Maryland.

Obs. Compare with S. granulosus.

Spirifer(?) costalis Castelnau. ?Upper Helderberg (Dev.).

Spirifer costalis Castelnau, Essai Systéme Silurien l'Amérique Septentrionale, 1843, p. 41, pl. 14, fig. 7.

Loc. Schoharie, New York.

Spirifer crispatus Hall and Clarke. Niagara (Sil.).

Spirifer crispatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 360, pl. 36, figs. 9, 10.

Loc. "Maryland."

Spirifer crispus (Hisinger). Niagara and Coralline (Sil.).

Terebratula crispa Hisinger, Svenska Vet.-Akad. Handlingar, 1826, tab. 7, fig. 4.

Delthyris staminea Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 105, fig. 3.

Spirifer crispus Hall, American Jour. Sci., XX, 1849, p. 228;—Pal. New York, II, 1852, p. 262, pl. 54, fig. 3; p. 328, pl. 74, fig. 9.—Beecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 75, pl. 6, figs. 6, 7.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 19, 20, 36, pl. 36, figs. 1–6.

Spirifera crispa Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 157, pl. 24, figs. 6–12, 19;—Eleventh Rep. State Geol. Indiana, 1882, p. 295, pl. 24, figs. 6–12, 19;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 61, figs. 1–6.

Loc. Europe; Lockport, Lewiston, and Schoharie, New York; Hamilton and Arisaig, Nova Scotia (Ami); Ontario; Waldron, Indiana.

Spirifer crispus simplex Hall. Niagara (Sil.).

Spirifera crispa var. Hall, Trans. Albany Institute, IV, 1863, p. 212.

Spirifera crispa var. simplex Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 157, pl. 24, figs. 1–5;—Eleventh Rep. State Geol. Indiana, 1882, p. 296, pl. 24, figs. 1–5.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 111, pl. 17, figs. 36, 37.

Spirifer crispus var. simplex Beecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 75, pl. 6, figs. 4, 5.

Loc. Waldron, Indiana; Louisville, Kentucky.

Spirifer cultrijugatus Yandell and Shumard=Spirifer acuminatus.

Spirifer cumberlandiæ Hall. Oriskany (Dev.).

Spirifer cumberlandiæ Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 63;—Pal. New York, III, 1859, p. 421, pl. 96, fig. 9.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 17, 36, pl. 33, figs. 16–23.

Digitized by Google

Spirifer cumberlandiæ Hall—Continued.

Spirifera cumberlandiæ Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 58, figs. 16–23.

Loc. Cumberland, Maryland.

Spirifer cuspidatus of American authors=Syringothyris carteri.

Spirifer cuspidatiformis Miller=Syringothyris texta.

Spirifer cyclopterus Hall. Lower Helderberg and Oriskany (Dev.).

Spirifer cycloptera Hall, Tenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1857, p. 58;—Pal. New York, III, 1859, p. 199, pl. 25, fig. 1.

Spirifera cycloptera Billings, Geol. Canada, 1863, p. 957, fig. 457;—Pal. Fossils, II, 1874, p. 48, pl. 3A, fig. 4.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 61, figs. 12, 13.

Spirifer cyclopterus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 36, pl. 36, figs. 12, 15.

Loc. Helderberg Mountains, New York; Gaspé and New Brunswick.

Spirifer cyrtinaformis Hall and Whitfield=Cyrtia cyrtiniformis.

Spirifer davisi Nettelroth. Hamilton (Dev.).

Spirifera davisi Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 112, pl. 12, figs. 1–4.

Loc. Falls of Ohio.

Spirifer deltoideus Herrick. Waverly (L. Carb.).

Spirifera deltoidea Herrick, Bull. Denison Univ., IV, 1888, p. 27, pl. 2, fig. 7.

Spirifer deltoideus Herrick, Geol. Ohio, VII, 1895, pl. 15, fig. 7.

Loc. Licking County, Ohio.

Spirifer desideratus Walcott. Lower Carboniferous.

Spirifera desiderata Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 217, pl. 7, fig. 8.

Loc. Eureka district, Nevada.

Spirifer disjunctus Sowerby. Chemung (Dev.).

Spirifera disjuncta Sowerby, Trans. Geol. Soc., 2d ser., V, 1840, pl. 53, fig. 8; pl. 54, figs. 12, 13.—Davidson, Mon. British Devonian Brach., Pal. Soc., 1864, p. 23, pl. 5, figs. 1–12; pl. 6, figs. 1–5.—Hall, Pal. New York, IV, 1867, p. 243, pl. 41, figs. 1–19; pl. 42, figs. 1–20;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, figs. 14–17.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 134.—Whiteaves, Cont. Canadian Pal., I, 1891, p. 221, pl. 29, fig. 4.

Delthyris perlatus Conrad, Fifth Ann. Rep. N. Y. Geol. Survey, 1841, p. 54.

Delthyris chemungensis Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 263.

Delthyris prolata Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 179, fig. 3.

Delthyris cuspidata Hall (non Martin), Geol. N. Y.; Rep. Fourth Dist., 1843, p. 270, fig. 1.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 829, fig. 683.

Delthyris disjuncta? Hall, Geology N. Y.; Rep. Fourth Dist., 1843, p. 269, fig. 3.

Delthyris acanthota Hall, Ibidem, 1843, p. 270, fig. 2.

Delthyris inermis Hall, Ibidem, 1843, p. 270, fig. 4.

Spirifer disjunctus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 21, 24, 27, 37, 49, pl. 30, figs. 14, 15, 17.—Herrick, Geol. Ohio, VII, 1895, pl. 23, fig. 11.

Loc. Europe; New York; Pennsylvania; Eureka district, Nevada; Peace, Hay, and Liards rivers, Canada.

Spirifer disjunctus occidentalis Whiteaves. Upper Devonian.

Spirifera disjuncta var. occidentalis Whiteaves, Cont. Canadian Pal., I, 1891, p. 222, pl. 29, fig. 5.

Loc. Hay River, Canada.

Digitized by Google

Spirifer disjunctus sulcifer Hall and Clarke. Chemung

Spirifera disjunctus var. sulcifer Hall and Clarke, Pal. New York, VI 1895, p. 361, pl. 30, fig. 16.

Loc. Near Olean, New York.

Spirifer disparilis Hall=Metaplasia disparilis.

Spirifer divaricatus Hall. Corniferous and Hamilton

Spirifer divaricata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857,

Spirifer venustus Hall, Thirteenth Rep. Ibidem, 1860, p. 82.

Spirifera divaricata Hall, Pal. New York, IV, 1867, p. 213, pl. 32, figs. 1 telroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 18 pl. 11, figs. 6–11; pl. 12, figs. 5–11.

Spirifer divaricatus Hall and Clarke, Pal. New York, VIII, Pt. II, 18 27, 39, pl. 38, figs. 15–17.

Loc. Schoharie, Stafford, Williamsville, York, etc., New York; Port Canada; Falls of Ohio; Lebanon, Kentucky.

Obs. Compare with S. multicostatus Castelnau.

Spirifer dubius Hall=Pentamerella dubia.

Spirifer dubius Nettelroth. ?Niaga

Spirifera dubia Nettelroth, Kentucky Fossil Shells, Mem. Kentucky vey, 1889, p. 115, pl. 33, figs. 23, 24.

Loc. Louisville, Kentucky.

Spirifer duodenarius (Hall). Upper Helderberg

Delthyris duodenaria Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 171

Spirifera duodenaria Billings, Canadian Jour., n. ser., V, 1861, p. 256, figs Geol. Canada, 1863, p. 372, fig. 394.—Hall, Pal. New York, IV, 18 pl. 27, figs. 13–16; pl. 28, figs. 24–33;—Second Ann. Rep. N. Y. St 1883, pl. 58, figs. 8–13.—Nettelroth, Kentucky Fossil Shells, Mem. Geol. Survey, 1889, p. 114, pl. 12, figs. 12, 13, 16.

Spirifera duodenaria? Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879,

Spirifer duodenarius Hall and Clarke, Pal. New York, VIII, Pt. II, 18 37, pl. 33, figs. 8–15.

Loc. New York, Ontario, Columbus, Ohio; Falls of Ohio; Rio Maecuru, of Para, Brazil.

Spirifer duplicatus Hall=Spirifer dupliplicatus.

Spirifer duplicicosta Phillips. Carbon

Spirifer duplicicostus Phillips, Geol. Yorkshire, II, 1829, p. 218, pl. 10,

Spirifera duplicicosta Etheridge, Quart. Jour. Geol. Soc. London, XX p. 628.

Loc. Europe; Feilden Isthmus, lat. 82° 43′.

Spirifer dupliplicatus (Conrad). Hamilton

Delthyris dupliplicata Conrad, Jour. Acad. Nat. Sci. Philadelphia, V p. 261, pl. 14, fig. 16.

Spirifera duplicata Hall, Pal. New York, IV, 1867, pp. 223, 236.

Loc. Near Smyrna, New York.

Obs. Compare with S. granulosus Conrad.

Spirifer eatoni Hall=Spirifer audaculus.

Spirifer elizæ Rathbun. Middle De

Spirifer elizæ (Hartt MS.) Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 187 pl. 8, figs. 15, 21; pl. 9, fig. 22.

Spirifera elizæ Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 28.

Loc. Erere, Province of Para, Brazil.

Digitized by Google

Spirifer engelmanni Meek and Worthen (non Meek)=Spirifer worthenanus.

Spirifer engelmanni Meek. Middle Devonian.

Spirifera engelmanni Meek, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 308.—Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p. 346, pl. 1, fig. 1.—King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 41, pl. 3, fig. 3.

Loc. Neils Valley, Utah; White Pine district, Nevada.

Spirifer eudora Hall. Niagara (Sil.).

Spirifera eudora Hall, Annual Rep. Geol. Survey Wisconsin, 1861, p. 25;—Geol. Rep. Wisconsin, I, 1863, p. 69, pl. 5; p. 436;—Trans. Albany Inst., IV, 1863, p. 211;—Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 370, pl. 13, figs. 5, 7;—Ibidem, Twenty-eighth Rep., 1879, p. 156, pl. 24, figs. 13–18;—Eleventh Rep. State Geol. Indiana, 1882, p. 294, pl. 24, figs. 13–18;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 51, figs. 19–21, 29.

Spirifer eudora Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 13, 35, pl. 21, figs. 19–21, 29.

Loc. Racine, Wisconsin; Waldron, Indiana; Louisville, Kentucky.

Spirifer euruteines Hall (non Owen)=S. fornacula.

Spirifer euruteines var. fornacula Hall=S. fornacula.

Spirifer euryteines Owen. Hamilton (Dev.).

Delthyris euruteines Owen, Rep. Geol. Expl. Iowa, Wisconsin, and Illinois, 1844, p. 69, pl. 12, fig. 9.

Spirifer euruteines Owen, Geol. Survey Wisconsin, Iowa, and Minnesota, 1852, p. 586, pl. 3, figs. 2, 6. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17924.]

Spirifer parryana Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 509, pl. 4, fig. 8.—Keyes, Geol. Surv. Missouri, V, 1895, p. 77, pl. 40, fig. 4.

Spirifer capax Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 520, pl. 7, fig. 7.

Spirifera parryana Billings, Canadian Jour., VI, 1861, p. 261, figs. 77, 78;—Geol. Canada, 1863, p. 386, fig. 422.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 52, figs. 8, 9.—Calvin, Bull. Lab. State Univ. Iowa, 1888, p. 19.

Spirifera fornacula Meek and Worthen (non Hall), Geol. Survey Illinois, III, 1868, p. 433, pl. 13, fig. 8.

Spirifera capax Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 52, figs. 15–17.

†Spirifera parryana Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 137, pl. 14, fig. 10.

Spirifer parryanus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 29, 31, 39, pl. 22, figs. 8, 9, 15–17.

Loc. Pine Creek and elsewhere in Iowa; Eureka district, Nevada; Bosanquet, Ontario, Canada.

Obs. Owen described this species in 1839, but it was not published until 1844. In 1841 Owen sent Professor Hall specimens from the Falls of the Ohio labeled S. euruteines. This species was again refigured in his report of 1852, where he cites the same localities as in 1844 (p. 32 last paragraph), adding Falls of Ohio and Columbus, Ohio. Professor Hall is correct in regarding the Ohio specimens as distinct from those of the Mississippi Valley, but is in error in thinking that figures 6–6b of the 1852 report are drawn from an Ohio Falls specimen. These figures are of the same specimen as of figure 9 of the 1844 report, which is from Pine Creek, Iowa. The type specimens are in the National Museum collection. Owen's figure 2 is the same species as Hall's S. capax, while his figure 6 is a small individual of S. parryana Hall. Professor Calvin has shown these two species to be identical. Therefore it follows that S. euryteines must be restricted to the specimens from the Mississippi Valley. For the specimens from the Falls of the Ohio S. fornaculus Hall will be the proper name.

Digitized by Google

Spirifer extenuatus Hall=Syringothyris extenuata.

Spirifer fasciger Owen (non Keyserling)=Spirifer cameratus.

Spirifer fastigatus Meek and Worthen (non Morton)=Spirifer mortonanus.

Spirifer fastigatus Morton. ?Lower Carboniferous.

Spirifer fastigatus Morton, American Jour. Sci., XXIX, 1836, p. 152, pl. 14, fig. 35.
Loc. Junior Furnace, Scioto County, Ohio.
Obs. Not recognizable.

Spirifer filicosta A. Winchell. Hamilton (Dev.).

Spirifera filicosta A. Winchell, Report Lower Peninsula of Michigan, 1866, p. 94.
Loc. Grand Traverse district, Michigan.

Spirifer (?) fimbriatus Morton Upper Carboniferous.

Spirifer fimbriatus Morton, American Jour. Sci., XXIX, 1836, p. 150, pl. 2, fig. 1.
Loc. Putnam Hill, Ohio.
Obs. Not recognizable.

Spirifer fimbriatus Hall=Reticularia fimbriata.

Spirifer fischeri Castelnau=Spirifer macropleura.

Spirifer foggi Nettelroth. Niagara (Sil.).

Spirifera foggi Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 117, pl. 32, figs. 28–31.
Loc. Louisville, Kentucky.

Spirifer forbesi Norwood and Pratten. Burlington (L. Carb.).

Spirifer forbesi Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 73, pl. 9, fig. 3.—Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 600, pl. 13, fig. 1.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 26, 38, pl. 37, fig. 18.
Spirifera forbesi Keyes, Geol. Survey Missouri, V, 1895, p. 80, pl. 40, fig. 3.
Loc. Burlington, Iowa; Hannibal, Louisiana, and Sedalia, Missouri.

Spirifer formosus Hall. Hamilton (Dev.).

Spirifer formosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 154.
Spirifera formosa Hall, Pal. New York, IV, 1867, p. 220, pl. 28, figs. 12–16.
Loc. Bakeoven, Illinois.

Spirifer fornacula Meek and Worthen (non Hall)=Spirifer euryteines.

Spirifer fornacula Hall. Hamilton (Mid. Dev.).

Spirifer fornacula Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 154.
Spirifera euruteines Hall (non Owen), Pal. New York, IV, 1867, p. 209, pl. 31, figs. 14–19.—White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, p. 504, pl. 4, figs. 4, 5;—Tenth Rep. State Geol. Indiana, 1881, p. 136, pl. 4, figs. 4, 5.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 115, pl. 6, figs. 1–7, 9, 11–17.
Spirifera euruteines var. fornacula Hall, Pal. New York, IV, 1867, p. 211, pl. 31, figs. 11–13.—Whitfield, Geol. Wisconsin, IV, 1882, p. 330, pl. 25, fig. 22.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 117, pl. 6, figs. 8, 10, 18–20.
Loc. Jackson County, Illinois; Falls of Ohio; Columbus, Ohio; Milwaukee, Wisconsin (Whitfield).
Obs. See remarks on S. euryteines Owen.

Spirifer fornax Hall. Hamilton (Dev.).

Spirifer fornax Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 155.
Loc. Illinois.

Digitized by Google

Spirifer franklini Meek=Reticularia franklini.

Spirifer fultonensis Worthen. Upper Carboniferous.

Spirifera fultonensis Worthen, Geol. Survey Illinois, V, 1873, p. 572, pl. 25, fig. 5.
Loc. Canton, Illinois.

Spirifer gaspensis Billings. Oriskany (Dev.).

Spirifera gaspensis Billings, Pal. Fossils, II, 1874, p. 44, pl. 3, fig. 8.
Loc. Gaspé.

Spirifer gibbosus Hall. Niagara (Sil.).

Spirifer gibbosus Hall, Ann. Rep. Geol. Survey Wisconsin, 1861, p. 25.
Spirifera gibbosa Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 370, pl. 13, figs. 6, 8.
Loc. Racine, Wisconsin.
Obs. Probably the same as S. eudora Hall.

Spirifer glabrus Davidson=Martinia glabra.

Spirifer glabrus var. contractus Meek and Worthen=Martinia glabra contracta.

Spirifer glabrus nevadensis Walcott=Reticularia nevadaensis.

Spirifer glanscerasus White=Martinia glanscerasi.

Spirifer granuliferus Hall=Spirifer granulosus.

Spirifer granulosus (Conrad). Hamilton (Dev.).

Delthyris granulosa Conrad, Third Ann. Rep. Geol. Survey N. Y., 1839, p. 65.
Delthyris granulifera Hall, Geology N. Y.; Rep. Fourth Dist., 1843, p. 206, fig. 1.
Delthyris congesta Hall, Ibidem, 1843, p. 206, fig. 2.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 828, figs. 670, 673.
Spirifer huroniensis Castelnau, Essai Système Silurien l'Amérique Septentrionale, 1843, p. 41, pl. 12, fig. 6.
Spirifer osteolatus Yandell and Shumard, Cont. Geol. Kentucky, 1847, p. 14.
Spirifer granulifera Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 163.
Spirifer arata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 161.
Spirifer clintoni Hall, Ibidem, 1857, p. 157.
Spirifer oweni Hall, Ibidem, 1857, p. 129.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 22, figs. 1–7.
Spirifera oweni Hall, Pal. New York, IV, 1867, p. 197, pl. 29, figs. 1–8;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 52, figs. 1–7.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 126, pl. 7, figs. 1–10.
Spirifera granulifera Hall, Pal. New York, IV, 1867, p. 223, pl. 36, figs. 1–13;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 53, figs. 1–15.
Spirifera arata Hall, Pal. New York, IV, 1867, p. 225.
Spirifer granulosus Hall, Pal. New York, VIII, Pt. II, 1893, pp. 29, 30, 31, 32, pl. 23, figs. 1–15; pl. 29, figs. 9–12.
Loc. Schoharie, Moscow, Darien, Canandaigua, etc., New York; Pennsylvania; Cumberland, Maryland; Virginia; Falls of Ohio; Alpena, Michigan.

Spirifer gregarius Clapp. Upper Helderberg (Dev.).

Delthyris gregaria Yandell and Shumard, Cont. Geol. Kentucky, 1847, pp. 9, 10. (Nomina nudum.)
Spirifer gregaria (Clapp MS.) Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 127.
Spirifera gregaria Billings, Canadian Jour., n. ser., VI, 1861, p. 260, figs. 74–76;—Geol. Canada, 1863, p. 372, fig. 391.—Hall, Pal. New York, IV, 1867, p. 195, pl. 28, figs. 1–11.—White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, pl. 4, figs. 10, 11;—Tenth Rep. State Geol. Indiana, 1881, p. 136, pl. 4, figs. 10, 11.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 119, pl. 8, figs. 9–13; pl. 10, figs. 6–10.

Digitized by Google

Spirifer gregarius Clapp—Continued.

Spirifer gregarius Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 17, 36, pl. 29, fig. 7; pl. 37, figs. 11, 12.

Loc. Falls of Ohio; Columbus, Ohio; Genesee and Erie counties, New York; Ontario.

Spirifer grieri Hall. Upper Helderberg (Dev.).

Spirifer grieri Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 127;—Pal. New York, IV, 1867, p. 194, pl. 27, fig. 29; pl. 28, figs. 17–23.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 24, 27, 38, pl. 30, figs. 9–13.

Spirifera grieri Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, figs. 9–13.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 120, pl. 9, figs. 8–14.

Loc. Clarence, Williamsville, etc., New York; Columbus, Ohio; Falls of Ohio.

Spirifer grimesi Hall. Kinderhook and Burlington (L. Carb.).

Spirifer grimesi Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 604, pl. 14, figs. 1–5.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 23, 25, 38, pl. 31, figs. 8, 16–19.

Spirifer allied to grimesi Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 628, pl. 25, fig. 5.

Spirifera grimesi Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 56, figs. 8, 16–19.—Keyes, Geol. Survey Missouri, V, 1895, p. 79.

Loc. Burlington, Iowa; Quincy, Illinois; Fielden Isthmus, lat. 82° 43′; Hannibal, Louisiana, Sedalia, etc., Missouri.

Spirifer guadalupensis Shumard=Reticularia guadalupensis.

Spirifer hannibalensis Swallow=Syringothyris carteri.

Spirifer hartti Rathbun. Middle Devonian.

Spirifera hartti Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 29.

Loc. Rio Maecuru, Province of Para, Brazil.

Spirifer hawkinsi Morris and Sharpe. Lower Devonian.

Spirifer hawkinsii Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 276, pl. 11, fig. 1.

Loc. Falkland Islands.

Spirifer hemicyclus Meek and Worthen. Oriskany (Dev.).

Spirifer hemicyclus Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 399, pl. 8, figs. 6, 7.

Loc. Union and Alexandria counties, Illinois.

Spirifer hemiplicatus Hall=Enteletes hemiplicatus.

Spirifer hesione Billings=Delthyris raricosta.

Spirifer hirtus White and Whitfield=Reticularia cooperensis.

Spirifer hobbsi Nettelroth. Hamilton (Dev.).

Spirifera varicosa var. Hall, Pal. New York, IV, 1867, p. 206, pl. 31, fig. 23.

Spirifera hobbsi Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 121, pl. 10, figs. 21, 22, 26–30, 35, 40.

Loc. Falls of Ohio.

Spirifer homfrayi Gabb=Spiriferina homfrayi.

Spirifer hungerfordi Hall. Chemung (Dev.).

Spirifer hungerfordi Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 501, pl. 4, fig. 1.—Tschernyschew, Mémoires du Comité Géologique de St. Petersbourg, III, 3, 1887, p. 62.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 23, 25, 37, pl. 29, fig. 6; pl. 37, figs. 26–30.—Webster, American Naturalist, XXII, 1888, p. 1101.

Loc. Rockford, Iowa.

Digitized by Google

Spirifer huroniensis Castelnau=Spirifer granulosus.

Spirifer huronensis A. Winchell. Portage (Dev.).

Spirifer huronensis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 406.
Loc. Port aux Barques, Michigan.

Spirifer imbrex Hall. Burlington (L. Carb.).

Spirifer imbrex Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 601, pl. 13, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 26, 38, pl. 31, figs. 11, 12.
Spirifera imbrex Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 56, figs. 11, 12.
Loc. Burlington, Iowa; Hannibal and Louisiana, Missouri.

Spirifer inæquivalvis Castelnau=Rhynchotrema inæquivalvis.

Spirifer incertus Hall. Burlington (L. Carb.).

Spirifer incerta Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 602, pl. 13, fig. 3.
Loc. Burlington, Iowa.

Spirifer inconstans Hall=Spirifer nobilis.

Spirifer increbescens Hall. Kaskaskia (L. Carb.).

Spirifer increbescens Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 706, pl. 27, fig. 6.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 27, 39, pl. 30, figs. 27–30; pl. 31, figs. 1–3.—Keyes, Geol. Survey Missouri, V, 1895, p. 82.
Spirifera increbescens Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, figs. 27–30; pl. 56, figs. 1–3.
Loc. Kaskaskia and Chester, Illinois; Kentucky.
Obs. Not synonymous with S. bisulcatus Sowerby, as stated by Meek and Safford. It has also been referred to S. trigonalis (Martin).

Spirifer increbescens americanus Swallow. Kaskaskia (L. Carb.).

Spirifer increbescens var. americana Swallow, Trans. St. Louis Acad. Sci., II, 1866, p. 410.
Loc. Illinois and Missouri.
Obs. Regarded by Keyes as a synonym for S. increbescens.

Spirifer increbescens transversalis Hall. Kaskaskia (L. Carb.).

Spirifer increbescens var. transversalis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 708, pl. 27, fig. 6.
Loc. Kaskaskia and Chester, Illinois.

Spirifer inequicostatus Owen=Spirifer cameratus.

Spirifer insolitus Winchell=Martinia ? insolita.

Spirifer intermedius Hall. Oriskany (Dev.).

Spirifer intermedia Hall (non Brongniart, 1829), Pal. New York, III, 1859, p. 424.
Loc. Cumberland, Maryland.

Spirifer inutilis Hall. Upper Devonian.

Spirifer inutilis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 505, pl. 4, fig. 4.
Spirifera inutilis Whiteaves, Cont. Canadian Pal., I, 1891, p. 223.
Loc. Independence, Iowa; Athabasca River, Canada.

Spirifer iowaensis Owen. Middle Devonian.

Spirifer iowensis Owen, Geol. Survey Iowa, Winconsin, and Minnesota, 1852, p. 585, pl. 3, fig. 1. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17925.]
Spirifer pennatus Owen (non Atwater), Ibidem, 1852, p. 585, pl. 3, figs. 3, 8. [Ibidem, Cat., 17919, 17920.]
Spirifer ligus Owen, Ibidem, 1852, p. 585, pl. 3, fig. 4, and pl. 3A, fig. 2 [Ibidem, Cat., 17921, 17922].—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 31, 39, pl. 22, figs. 19–24; pl. 29, fig. 13.—Keyes, Geol. Survey Missouri, V, 1895, p. 77.

Digitized by Google

Spirifer iowaensis Owen—Continued.

Spirifer cedarensis Owen, Geol. Survey Iowa, Wisconsin, and Minnesota, 1852, p. 586, pl. 3, fig. 5. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17923.]

Spirifer pennata Hall, Geol. Survey, Iowa, I, Pt. II, 1858, p. 510, pl. 5, fig. 1.

?Spirifera allied to pennata Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 633, pl. 29, fig. 1.

Spirifera atwaterana Miller, Proc. Davenport Acad. Sci., 1878, p. 222.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 107.

Spirifera pennata Whitfield, Geol. Wisconsin, IV, 1882, p. 330, pl. 26, fig. 4.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 52, figs. 19–24.

Loc. New Buffalo, Independence, etc., Iowa; Rock Island, Illinois; Milwaukee, Wisconsin; Falls of Ohio; south of Cape Joseph Henry, lat. 82° 42′.

Obs. Owen's type specimens of S. iowaensis, S. pennatus, S. ligus, and S. cedarensis are preserved in the National Museum collection. The six specimens of these species show, when compared with a large series of similar shells from Iowa, that they are but variations of a very variable and widely distributed Spirifer of the Devonian of the Mississippi Valley. The width and degree of curvature of the ventral area and the length of the cardinal line are extremely variable features in S. iowaensis. Upon these characters Owen has based his species. The name S. iowaensis has been selected not only because it is very appropriate but also since it is the first one described. S. parryanus is another closely allied species, but can be separated generally by its wider ventral area and in the cardinal lines not being drawn out into more or less mucronate extensions.

Spirifer kelloggi Swallow. Keokuk (L. Carb.).

Spirifera kelloggi Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 86.—Keyes, Geol. Survey Missouri, V, 1895, p. 81.

Spiriferina kelloggi Safford, Geol. Tennessee, 1869, p. 360.

Loc. Keokuk, Iowa; Tennessee.

Spirifer kennicotti Meek. Middle Devonian.

Spirifer kennicotti Meek, Trans. Chicago Acad. Sci., I, 1868, p. 101, pl. 14, fig. 9.

Loc. Mackenzie River Valley, Northwest Territory, Canada.

Obs. This species is much like S. pennatus Miller, but with the fold and sinus plicated. It is unlike S. disjunctus, to which it has been referred by Whiteaves, in its shallow visceral cavity.

Spirifer kentuckiensis Shumard=Spiriferina cristata.

Spirifer kentuckiensis var. propatula Swallow=Spiriferina cristata.

Spirifer keokuk Hall. Keokuk (L. Carb.).

Spirifer striatus? var. attenuatus? Owen (non Sow.), Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 3A, fig. 8. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17944.]

Spirifer keokuk Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 642, pl. 20, figs. 3 and 2d;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, figs. 21–24.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 27, 38, pl. 30, figs. 21–24; pl. 37, figs. 13–15.

Spirifer keokuk var. Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 676, pl. 24, fig. 4.

Spirifer keokuk? Meek, Bull. U. S. Geol. Geogr. Survey Terr., II, 1876, p. 355, pl. 1, fig. 3.

Spirifera keokuk Keyes, Geol. Survey Missouri, V, 1895, p. 81, pl. 40, fig. 2.

Loc. Keokuk, Iowa; Nauvoo and Warsaw, Illinois; Utah; Rushville and Loudonville, Ohio (Herrick).

Obs. See S. littoni.

Digitized by Google

Spirifer keokuk shelbyensis Swallow. Warsaw (L. Carb.).

Spirifer keokuk var. shelbyensis Swallow, Trans. St. Louis Acad. Sci., II, 1866, p. 410.

Loc. Shelby County, Missouri.

Spirifer knappanus Nettelroth=Reticularia knappiana.

Spirifer lateralis Hall. Warsaw (L. Carb.).

Spirifer lateralis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 661, pl. 23, fig. 7.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 32, figs. 1-3; pl. 37, fig. 19.

†Spirifera lateralis Hall, Second Ann. Rep. N. Y. State Geol., 188', pl. 57, figs. 1-3.

Loc. Clifton and Warsaw, Illinois.

Spirifer latior Swallow. Chouteau (L. Carb.).

Spirifer latior Swallow, Trans. St. Louis Acad. Sci., II, 1863, p. 86.

Loc. Cooper County, Missouri.

Obs. Compare with S. marionensis.

Spirifer lævigatus Swallow=Martinia lævigata.

Spirifer lævis Hall=Reticularia lævis.

Spirifer laminosus Geinitz (non McCoy)=Spiriferina cristata.

Spirifer leidyi Norwood and Pratten. St. Louis (L. Carb.).

Spirifer leidyi Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, III, 1854, p. 72, pl. 9, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 27, 39, pl. 30, figs. 25, 26.

Spirifer bifurcatus Hall, Trans. Albany Institute, IV, 1857, p. 8.

Spirifera bifurcata Whitfield, Bull. American Mus. Nat. Hist., I, 1882, p. 47, pl. 6, figs. 13-15.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 326, pl. 29, figs. 13-15.

Spirifera leidyi Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, figs. 25, 26.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 216, pl. 18, fig. 4.—Keyes, Geol. Survey Missouri, V, 1895, p. 82.

Loc. Chester, Illinois; Spergen Hill, Indiana; Princeton, Kentucky; Utah; Eureka district, Nevada.

Spirifer leidyi chesterensis Swallow. Kaskaskia (L. Carb.).

Spirifer leidyi var. chesterensis Swallow, Trans. St. Louis Acad. Sci., II, 1866, p. 409.

Loc. "Above the St. Louis limestone," Missouri.

Obs. Regarded by Keyes as a synonym for S. leidyi.

Spirifer leidyi merimacensis Swallow. Warsaw (L. Carb.).

Spirifer leidyi var. merimacensis Swallow, Trans. St. Louis Acad. Sci., II, 1866, p. 410.

Loc. Barrets Station, St. Louis County, Missouri.

Obs. Regarded by Keyes as a synonym for S. leidyi.

Spirifer ligus Owen=S. iowaensis.

Spirifer lineatoides Swallow=Reticularia pseudolineata.

Spirifer lineatus of American authors=Reticularia perplexa.

Spirifer lineatus striatolineatus Swallow=Reticularia perplexa striatilineata.

Spirifer linguiferoides Forbes=Spiriferina rostrata.

Spirifer littoni Swallow. St. Louis (L. Carb.).

Spirifer littoni Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 646.

Loc. St. Louis County, Missouri.

Obs. Regarded by Keyes as a synonym for S. keokuk.

Digitized by Google

Spirifer logani Hall. Keokuk (

Spirifer logani Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 647, pl. 20, fi figs. 1, 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 2 figs. 7, 8.

Spirifera logani A. Winchell, Proc. American Phil. Soc., XII, 1870, p. Second Ann. Rep. N. Y. State Geol., 1883, pl. 57, figs. 7, 8.—K Survey Missouri, V, 1895, p. 81.

Loc. Nauvoo, Illinois; Clark County, Missouri; Tennessee.

Spirifer lyelli de Verneuil=Spirifer pennatus.

Spirifer macbridei Calvin. Upper I

Spirifera macbridei Calvin, American Jour. Sci., 3d ser., XXV, 188 Calvin, Bull. Lab. Nat. Hist. State Univ. Iowa, II, 1892, p. 166, p

Spirifer macbridii Hall and Clarke, Pal. New York, VIII, Pt. II, 1 31, 39, pl. 25, figs. 9–16 (?17–19).

Loc. Rockford, Iowa.

Spirifer macconathei Nettelroth. Hamilto

Spirifera macconathii Nettelroth, Kentucky Fossil Shells, Mem. Kent Survey, 1889, p. 123, pl. 11, figs. 1–5.

Loc. Falls of Ohio.

Spirifer macra Meek (non Hall)=Spirifer strigosus.

Spirifer macrus Hall. Upper Helderber

Spirifer macra Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p.

Spirifera macra Hall, Pal. New York, IV, 1867, p. 190, pl. 27, figs. 17–2 Ann. Rep. N. Y. State Geol., 1883, pl. 59, figs. 1–3.

Spirifer macrus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp 34, figs. 1–3.

Loc. Schoharie, Williamsville, etc., New York; Columbus, Ohio.

Spirifer macronotus Hall=S. audaculus macronotus.

Spirifer macropleura (Conrad). Lower Helderber

Delthyris macropleura Conrad, Fourth Ann. Rep. N. Y. Geol. Surv 207.—Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 120, fig. 1 Ibidem, Rep. First Dist., 1843, p. 343, fig. 1.

Spirifer macropleurus Castelnau, Essai Système Silurien l'Amérique onale, 1843, p. 41, pl. 13, fig. 5.

Spirifer fischeri Castelnau, Ibidem, 1843, p. 42, pl. 13, fig. 4.

Spirifer macropleura Hall, Pal. New York, III, 1859, p. 202, pl. 27, fig fig. 8.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 20, figs. 22–24, 27.

Spirifera macropleura Billings, Geol. Canada, 1863, p. 957, fig. 456;— land Soc. Nat. Hist., 1863, p. 117, pl. 3, fig. 16.—Hall, Second N. Y. State Geol., 1883, pl. 51, figs. 22–24, 27.

Loc. Schoharie, Carlisle, Catskill, etc., New York; Square Lake, Ma berland, Maryland; Perry County, Tennessee.

Spirifer macrothyris Hall. Upper Helderber

Spirifer macrothyris Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 185 Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 29, 31, 39, 16–18.

Spirifera macrothyris Hall, Pal. New York, IV, 1867, p. 202, pl. 30, fig Second Ann. Rep. N. Y. State Geol., 1883, pl. 53, figs. 16–18.

Loc. Williamsville and Clarence Hollow, New York; Cayuga, Ontari bus, Ohio.

Digitized by Google

Rathbun. Middle Devonian.
is Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 30.
Province of Para, Brazil.
ngs=Martinia maia.

Upper Helderberg (Dev.).
l, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 128.
ll, Pal. New York, IV, 1867, p. 211, pl. 31, figs. 20–30.
Columbus, Ohio; Williamsville, New York.
agen. Upper Carboniferous.
arcou (non Martin), Geol. North America, 1858, p. 49, pl. 7,

aagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 510, pl. 47.
, California; Tigeras, New Mexico; Vancouver Island.

Hamilton (Dev.).
ll, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 158, figs.
Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 29, 39, pl. 22,

all, Pal. New York, IV, 1867, p. 226, pl. 37, figs. 10–20;—Sec-
N. Y. State Geol., 1883, pl. 52, figs. 10–14.
ayuga and Seneca lakes, New York; Columbus, Ohio (Whit-

Shumard. Chouteau (L. Carb.).
s Shumard, Geol. Rep. Missouri, 1855, p. 203, pl. C, fig. 8.—Hall,
owa, I, Pt. II, 1858, p. 501, pl. 6, fig. 1.—Hall and Clarke, Pal.
I, Pt. II, 1893, pp. 25, 38, pl. 31, fig. 15.—Herrick, Geol. Ohio,
5, fig. 2.

is A. Winchell, Proc. American Phil. Soc., XII, 1870, p. 252.—
nn. Rep. N. Y. State Geol., 1883, pl. 56, fig. 15.—Herrick, Bull.
III, 1888, p. 43, pl. 6, figs. 2–4; pl. 7, fig. 11; IV, 1888, p. 26,
eyes, Geol. Surv. Missouri, V, 1895, p. 78.
nsis Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol.
. 124.
Hannibal, Missouri; Portsmouth, Sciotoville, etc., Ohio;

S. osagensis, S. missouriensis, and S. vernonensis.
all=Spirifer audaculus.
ow. Burlington (L. Carb.).
low, Trans. St. Louis Acad. Sci., I, 1860, p. 645.
ine counties, Missouri.
Meek=Martinia meristoides.
s Hall=Delthyris mesicostalis.
Hall. Portage and Chemung (Dev.).
lis Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 269, fig. 1.
is Emmons, Manual of Geology, 1860, p. 151.
lis Hall, Pal. New York, IV, 1867, p. 242, pl. 40, figs. 14–22,

Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 14, 35,
.
rtlandville, Cayuta Creek, and Ithaca, New York.
=Cyrtia meta.
anus Roemer=Spirifer cameratus.

Digitized by Google

Spirifer mexicanus Shumard. Upper Carboniferous.

Spirifera Mexicana Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 292, pl. 11, fig. 4, and p. 390.

Loc. Guadalupe Mountains, New Mexico and Texas.

Spirifer missouriensis Swallow. Chouteau (L. Carb.).

Spirifer missouriensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 643.

Loc. Cooper County, Missouri.

Obs. Regarded by Keyes as a synonym for S. marionensis.

Spirifer modestus Hall=Reticularia modesta.

Spirifer mortonanus Miller. Keokuk (L. Carb.).

Spirifera fastigata Meek and Worthen (non Worthen), Proc. Acad, Nat. Sci. Philadelphia, 1870, p. 36;—Geol. Survey Illinois, VI, 1875, p. 521, pl. 30, fig. 3.

Spirifera mortonana Miller, American Pal. Fossils, 2d ed., 1883, p. 298.

Spirifer mortonanus Hall and Clarke, Pal, New York, VIII, Pt. II, 1893, pp. 26, 38, pl. 38, figs. 18, 19.

Loc. Crawfordsville, Indiana; Kings Mountain and Lebanon, Kentucky.

Spirifer mucronatus Conrad=Spirifer pennatus.

Spirifer multicostatus Castelnau. ?Corniferous (Dev.).

Spirifer multicostatus Castelnau, Essai Système Silurien l'Amérique Septentrionale, 1843, p. 42, pl. 12, fig. 3.

Loc. Schoharie, New York.

Obs. See S. divaricatus.

Spirifer multigranosus Worthen=Spirifer texasanus.

Spirifer multistriata Hall=Trematospira multistriata.

Spirifer mundulus Rowley. Burlington (L. Carb.).

Spirifera mundula Rowley, American Geologist, XII, 1893, p. 307, pl. 14, figs. 10–12.

Loc. Louisiana, Missouri.

Spirifer murchisoni Castelnau. Oriskany (Dev.).

Spirifer murchisoni Castelnau, Essai Système Silurien l'Amérique Septentrionale, 1343, p. 41, pl. 12, figs. 1, 2.

Spirifer arrecta Hall, Pal. New York, III, 1859, p. 422, pl. 97, figs. 1, 2.

Spirifera arrecta Billings, Geol. Canada, 1863, p. 960, fig. 466.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 58, figs. 24–27.

Spirifer sp. a A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII, 1892, p. 67, pl. 4, fig. 22.

Spirifer arrectus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 17, 19, 37, pl. 33, figs. 24–27.

Loc. Schoharie and Albany counties, New York; Cumberland, Maryland; Cayuga, Ontario; near Totora, Bolivia.

Obs. Castelnau's figures prove conclusively that he was the first to describe this species.

Spirifer mysticensis Meek. Lower Carboniferous.

Spirifera mysticensis Meek, Sixth Ann. Rep. U. S. Geol. Survey Terr., 1873, p. 466.—Miller, North American Geol. and Pal., 1889, p. 374.

Loc. Outlet of Mystic Lake, Montana.

Spirifer neglectus Hall. Keokuk (L. Carb.).

Spirifer neglectus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 643, pl. 20, fig. 5.

Spirifera neglecta Meek and Worthen, Geol. Survey Illinois, VI, 1875, p. 523, pl. 30, figs. 1c, 2a.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 217, pl. 18, fig. 10.

Digitized by Google

ll—Continued.

a de Koninck, Annales du Musée Royal d'Historie Nat. de
1887, p. 134, pl. 31, figs. 10–15.
; Warsaw and Nauvoo, Illinois; Eureka district, Nevada;

all. Waverly (L. Carb.).
i Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 56, figs.

Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 362,
0.
.

(Conrad). Niagara (Sil.).
sis Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p.
l. N. Y.; Rep. Fourth Dist., 1843, p. 105, fig. 1.
s Hall, Pal. New York, II, 1852, p. 264, pl. 54, fig. 5.—Hall
l. New York, VIII, Pt. II, 1893, pp. 14, 35, pl. 21, figs. 1–4, 25;

is Billings, Canadian Nat. Geol., I, 1856, p. 137, pl. 2, fig. 8;—
1863, p. 317, fig. 329.—Hall, Second Ann. Rep. N. Y. State
51, figs. 1–4, 25.
hester, etc., New York; Osgood, Indiana.

oligoptychus Roemer. Niagara (Sil.).
sis var. oligoptychus Roemer, Sil. Fauna West. Tennessee,
5, fig. 8.
rus Safford, Geol. Tennessee, 1869, p. 321.
y, Tennessee.
S. eudorus Hall and S. macropleurus Conrad.

Dawson. Oriskany (Dev.).
is Dawson, Acadian Geology, 3d ed., 1878, p. 499, fig. 176;—
Geol., n. ser., IX, 1879, p. 3.
Nova Scotia.

nde. Niagara (Sil.).
rande, Ueber die Brach. der Sil. Schicht von Böhmen, 1847.—
e, Pal. New York, VIII, Pt. II, 1893, pp. 14, 35, pl. 29, fig. 16;

McChesney, New Pal. Fossils, 1861, p. 84.
Hall, Ann. Rep. Geol. Survey Wisconsin, 1861, p. 26;—Geol.
, I, 1862, p. 69, fig. 6; p. 436.
all, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 372,
16.
McChesney, New Pal. Fossils, 1868, p. 84.
nsin; Chicago, Illinois.

a Hall=Spiriferina norwoodana.
leek=Cyrtia norwoodi.

us Miller. Burlington (L. Carb.).
cana Miller, Jour. Cincinnati Soc. Nat. Hist., IV, 1881, p. 314,

ining district, New Mexico.

illings=Reticularia nympha.
bb=Spiriferina obtusa.

Digitized by Google

Spirifer octocostatus Hall. Lower Helderberg (Dev.).

Spirifer octocostata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 62;—Pal. New York, III, 1859, p. 205, pl. 28, fig. 4.

Loc. Cumberland, Maryland.

Spirifer octoplicatus Hall=Spiriferina cristata.

Spirifer opimus Hall=Spirifer rockymontanus.

Spirifer orbignyi Morris and Sharpe. Lower Devonian.

Spirifer orbignii Morris and Sharpe, Quart. Jour. Geol. Soc. London, II, 1846, p. 276, pl. 11, fig. 3.

Loc. Falkland Islands.

Obs. Probably identical with S. antarcticus.

Spirifer oregonensis Shumard. Upper Carboniferous.

Spirifer oregonensis Shumard, Trans. St. Louis Acad. Sci., II, 1863, p. 108.

Loc. Near Fort Filmore, New Mexico.

Spirifer orestes Hall and Whitfield. Chemung (Dev.).

Spirifera orestes Hall and Whitfield, Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1872, p. 237, pl. 11, figs. 16–20.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 55, fig. 20.

Spirifer orestes Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 27, 38, pl. 30, fig. 20.

Loc. Rockford, Iowa; Naples, New York.

Obs. Compare with S. strigosus.

Spirifer osagensis Swallow. Chouteau (L. Carb.).

Spirifer osagensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 641.

Loc. Pettis County, Missouri.

Obs. Regarded by Keyes as a synonym for S. marionensis.

Spirifer ovalis Phillips. Carboniferous.

Spirifer ovalis Phillips, Geol. Yorkshire, II, 1836, p. 219, pl. 10, fig. 5.—Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 629.

Loc. Europe. Feilden Isthmus, lat. 82° 43′.

Spirifer oweni Hall=Spirifer granulosus.

Spirifer paradoxus (Schlotheim). Corniferous (Dev.).

Terebratula paradoxa Schlotheim, Petrefactenkunde, VII, 1813, p. 249, tab. 2, fig. 6.

Spirifer paradoxus? Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 415, pl. 10, fig. 2.

Loc. Europe; Union and Jackson counties, Illinois.

Spirifer parryana Hall=S. euryteines Owen.

Spirifer peculiaris Shumard. Kinderhook (L. Carb.).

Spirifer? peculiaris Shumard, Geol. Rep. Missouri, 1855, p. 202, Pl. C, fig. 7.

Spirifera (Martinia) peculiaris White, Wheeler's Expl. and Survey west 100th Meridian, IV, 1875, p. 90, pl. 5, fig. 7.

Loc. Cooper County, Missouri; Mountain Spring, Nevada.

Spirifer pedroanus Rathbun. Middle Devonian.

Spirifera pedroana (Hartt) Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 237, pl. 8, figs. 1–9, 13, 14, 16–20;—Proc. Boston Soc. Nat. Hist., XX, 1879, p. 27.

Loc. Erere and Province of Para, Brazil.

Spirifer pennatus Owen=Spirifer iowaensis.

Digitized by Google

water). Marcellus, Hamilton, and Chemung (Dev.).
a Atwater, American Jour. Sci. Arts, II, 1820, p. 244, pl. 1,

ta Conrad, Fifth Ann. Rep. Geol. Survey New York, 1841, p.
Geol. N. Y.; Rep. Third Dist., 1842, p. 150, fig. 3.—Hall,
ourth Dist., 1843, p. 198, figs. 2, 3; p. 205, fig. 3 (non p. 270,
atus posterus).—(Conrad) Hall, Fifteenth Rep. N. Y. State
, 1862, pl. 11, fig. 18.
astelnau, Essai Syst. Silurien l'Amérique Septentrionale, 1843,
n Fischer).
rneuil, Ibidem, 1843, p. 43.
Billings, Canadian Nat. Geol., I, 1856, p. 474, pl. 7, figs. 9, 10.—
ennsylvania, II, 1858, p. 828, fig. 668.
a Billings, Canadian Jour., n. ser., VI, 1861, p. 254, figs. 59–
da, 1863, p. 386, fig. 424.—Hall, Pal. New York, IV, 1867, p.
1–32.—Nicholson, Pal. Prov. Ontario, 1874, p. 80.—Whitfield,
, IV, 1882, p. 328, pl. 25, figs. 27, 28.—Hall, Second Ann. Rep.
., 1883, pl. 59, figs. 13–22.—Calvin, American Geologist, I, 1888,
th, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889,
gs. 10, 11.
s var. Williams, Bull. Geol. Soc. America, I, 1890, pl. 12,

Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 14,
. 8; pl. 34, figs. 13–22.
nnsylvania, Maryland, Virginia; Bosanquet, Ontario; Mil-
nsin.
cimen was found in the drift of Ohio. Mr. Miller is correct
the same as the well-known S. mucronatus.

terus Hall and Clarke. Chemung (Dev.).
a (partim) Hall, Geol. New York; Rep. Fourth Dist., 1843,

s var. posterus Hall and Clarke, Pal. New York, VIII, Pt. II,
34, figs. 27-31.
nty, New York.

iensis Williams. Tully (Dev.).
s var. tulliensis Williams, Bull. Geol. Soc. America, I, 1890,
g. 12.
New York.

Orbigny. Carboniferous.
d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842,
15.
, Bolivia.

Hall=Trematospira perforata.

Meek and Worthen. Corniferous (Dev.).
a Meek and Worthen, Geol. Survey Illinois, III, 1868, p. 414,

o, Union County, Illinois.
Keyes as a synonym for S. ligus=S. iowaensis.

us Hall=Delthyris perlamellosa.
McChesney=Reticularia perplexa.
6

Digitized by Google

Spirifer pertenuis Hall. Hamilton (Dev.).

Spirifer pertenuis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 163.

Spirifera perextensa Hall, Pal. New York, IV, 1867. p. 236.

Loc. Cumberland, Maryland (Whitfield).

Obs. Compare with S. macronota Hall.

Spirifer pharovicinus A. Winchell. Huron (Dev.).

Spirifera pharovicina A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 406.

Loc. Port aux Barques, Michigan.

Spirifer pinonensis Meek. Lower to Upper Devonian.

Spirifer (Trigonotreta) pinonensis Meek, Proc. Acad. Nat. Sci. Philadelphia, 1870, p. 60;—King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 45, pl. 1, fig. 9.

Spirifer (Trigonotreta) argentarius Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 42, pl. 4, fig. 4.

Spirifera pinonensis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 138, pl. 4, fig. 1.

Loc. White Pine and Eureka districts, Nevada.

Spirifer planoconvexus Shumard=Ambocœlia planiconvexa.

Spirifer plenus Hall=Syringothyris plena.

Spirifer plicatella of authors=Spirifer radiatus.

Spirifer pluto Clarke. Genesee (Dev.).

Spirifera pluto Clarke, Bull U. S. Geol. Survey, 16, 1885, p. 31, pl. 3, fig. 12.

Loc. Ontario County, New York.

Obs. See Leiorhynchus hecate Clarke.

Spirifer præmatura Hall=Reticularia præmatura.

Spirifer propinquus Hall=Syringothyris texta.

Spirifer prorus Conrad=Spirifer acuminatus.

Spirifer pseudolineatus Hall=Reticularia pseudolineata.

Spirifer pulchrus Meek=Spiriferina pulchra.

Spirifer pyramidalis Hall=Cyrtina pyramidalis.

Spirifer pyxidatus Hall=Metaplasia pyxidata.

Spirifer quichuus d'Orbigny. Devonian.

Spirifer quichua d'Orbigny, Voyage dans l'Amérique Méridionale, Pal., 1842, p. 37, pl. 2, fig. 21.

Loc. Chuquisaca, Bolivia.

Spirifer racinensis McChesney=Spirifer nobilis.

Spirifer radiatus Sowerby. Clinton and Niagara (Sil.).

Spirifer plicatella var. radiata Sowerby, Mineral Conchology, V, 1825, p. 493, figs. 1, 2.

Delthyris bialveata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 261, pl. 14, fig. 17.

Delthyris radiata Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 105, fig. 2.

Spirifer radiata Hall, Pal. New York, II, 1852, pp. 66, 265, pl. 22, figs. 2d–25 (non 2a–2c=Cyrtia meta); pl. 54, fig. 6.

Spirifera radiata Billings, Canadian Nat. Geol., I, 1856, p. 135, pl. 2, figs. 2, 3;—Geol. Canada, 1863, p. 317, fig. 328.—Hall and Whitfield, Twenty-seventh Rep. N. Y. State Cab. Nat. Hist., 1875, pl. 9, figs. 17, 18.—Hall, Twenty-eighth Rep. Ibidem, 1879, p. 157, pl. 24, figs. 20–30.—White, Second Ann. Rep. Indiana Bureau of Statistics and Geol., 1880, p. 497, pl. 3, figs. 5, 6;—Tenth Rep. State Geol. Indiana, 1881, p. 129, pl. 3, figs. 5, 6.—Hall, Eleventh

Digitized by Google

verby—Continued.

882, p. 296, pl. 24, figs. 20–30.—Whitfield, Geol. Wisconsin, IV, . 17, figs. 1, 2.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, 13, 26 (†14–17).—Nettelroth, Kentucky Fossil Shells, Mem. . Survey, 1889, p. 130, pl. 29, figs. 13–16.—Foerste, Proc. Boston , XXIV, 1890, p. 313, pl. 5, fig. 6.

eecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 77, pl. 6, ll and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 13, 35, pl. , 26 (†14–18).

us Shaler (non Hall), Bull. Mus. Com. Zool., 4, 1865, p. 70.
Billings, Catalogue Silurian Fossils of Anticosti, 1866, p. 48.
var. radiata Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 13, figs. 9–11.

xport, Rochester, etc., New York; Hamilton, Ontario; Squa- Brunswick; Waldron and Osgood, Indiana; Louisville, Ken- rland Gap, Tennessee; Bridgeport, Illinois; Racine, Wauwa- aukee, Wisconsin.

Hall=Delthyris raricosta.

(Conrad). †Oriskany (Dev.).

Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 265.
Mountains in Middle Silurian limestone."
me as Metaplasia pyxidata Hall.

Meek=Reticularia fimbriata.

us Marcou. Upper Carboniferous.

tani Marcou, Geol. North America, March, 1858, p. 50, pl. 7,

l, Geol. Survey Iowa, I, Pt. II, December, 1858, p. 711.
icosa McChesney, New Pal. Fossils, 1860, p. 44;—Trans. Chi- , I, 1868, p. 35, pl. 1, fig. 4.
erby, Bull. Cornell University, I, 1874, p. 15, pl. 1, fig. 4; . 4, fig. 12.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, .—Herrick, Bull. Denison Univ., II, 1887, p. 44, pl. 2, fig. 23.
reta) opima Meek, Pal. Ohio, II, 1875, p. 329, pl. 19, figs. 14a– ing's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 88, pl. 9, fig. 6.
ntana White, Wheeler's Expl. and Survey west 100th Merid., 4, pl. 11, fig. 9.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, Geol. Survey Missouri, V, 1895, p. 84.
ontana† Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 584, pl. ol. Ohio, VII, 1895, p. 471, pl. 9, fig. 20.
all and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 27, 39,

Canyon of San Antonio, New Mexico; Oquirrh Range, Utah; a; Missouri; Illinois; Indiana; Ohio; Maryland; West Vir- lim and Itaituba, Brazil; †Chester group at Newtonville, Ohio

sis.

Hall. Keokuk (L. Carb.).

Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 641, pl. 20, fig. 2.
Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 26,

Iowa.

Digitized by Google

Spirifer rostellum Hall and Whitfield. Niag

Spirifera rostellum Hall and Whitfield, Twenty-fourth Rep. N. Y. Stat Hist., 1872, p. 182;—Hall, Twenty-seventh Rep. Ibidem, 1875, pl. 13.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Su p. 129, pl. 29, fig. 25; pl. 27, figs. 17–19.

Spirifera (Cyrtia) rostellum Foerste, Proc. Boston Soc. Nat. Hist., X p. 313, pl. 5, fig. 5.

Loc. Louisville, Kentucky; Collinsville, Alabama.

Spirifer rostratus Morton. Upper Carbo

Spirifer rostrata Morton, American Jour. Sci. Arts, 1836, p. 152, pl. 14

Loc. Junior Furnace, Scioto County, Ohio.

Obs. Poorly defined. May be a species of Athyris.

Spirifer rugicostus Hall=Delthyris rugicosta.

Spirifer saffordi Hall. Lower Helderber

Spirifer saffordi Hall, Pal. New York, III, 1859, p. 203, pl. 28, fig. 2.

Loc. Decatur County, Tennessee; Hudson, New York.

Spirifer scobina Meek. Carbo

Spirifera scobina Meek, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 3

Spirifer (Spiriferina?) scobina Meek, Simpson's Rep. Expl. Great I Utah, 1876, p. 351, pl. 2, fig. 5.

Spirifera (Trigonotreta) scobina Meek, King's U. S. Geol. Expl. 40th 1877, p. 90, pl. 9, fig. 1.

Loc. Divide between Long and Ruby Valleys, Utah.

Spirifer sculptilis Hall=Delthyris sculptilis.

Spirifer segmentum Hall. Upper Helderber

Spirifer segmentus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857

Spirifera segmenta Hall, Pal. New York, IV, 1867, p. 207, pl. 31, fig Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Surv 132, pl. 13, figs. 36–38.

Loc. Falls of Ohio; Columbus, Ohio.

Spirifer semiplicatus Hall=Reticularia cooperensis.

Spirifer setigerus Hall=Reticularia setigera.

Spirifer sheppardi Castelnau=Platystrophia biforata.

Spirifer sillanus A. Winchell. Waverly (I

Spirifera sillana A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863

Loc. Near Cuyahoga Falls, Ohio.

Spirifer similior Winchell and Marcy. Niaga

Spirifera (Martinia) similior W. and M., Mem. Boston Soc. Nat. Hi p. 93.

Pentamerus similior Hall, Twentieth Rep. N. Y. State Cab. Nat. I p. 397.

Loc. Bridgeport, Illinois.

Obs. This shell has spirals.

Spirifer solidirostris White=Spiriferina solidirostris.

Spirifer sowerbyi Castelnau (non Fischer)=Spirifer pennatus.

Spirifer spinosus Norwood and Pratten=Spiriferina spinosa.

Spirifer striatiformis Meek. Waverly (I

Spirifera (Trigonotreta) striatiformis Meek, Pal. Ohio, II, 1875, p. 280, p

Spirifer striatiformis Herrick, Bull. Denison Univ., III, 1888, p. 44, pl pl. 6, figs. 6, 7;—Geol. Ohio, VII, 1895, pl. 15, fig. 9.

Loc. Sciotoville and Licking County, Ohio.

Digitized by Google

rcou (non Martin)=Spirifer marcoui.

tin). Carboniferous.

Iartin, Petrefacta Derbiensia, 1809, pl. 23.

vidson, Mon. British Carb. Brach., Pal. Soc., 1857, p. 19, pl. 2, , figs. 2–6.—White, Wheeler's Expl. and Survey west of 100th 75, pp. 88, 134, pl. 5, fig. 10.—Hall and Whitfield, King's U. S. h Parl., IV, 1877, p. 269, pl. 5, figs. 13–15.—Hartt, Dawson's y, 3d ed., 1878, p. 301.—Miller, Jour. Cincinnati Soc. Nat. p. 2.

ng, Nevada; Oquirrh Mountains, Utah; Lake Valley mining exico; Windsor, Nova Scotia.

enuatus Owen=S. keokuk.

lticostatus Toula=Spirifer condor.

olicatus Marcou=Spirifer camaratus.

ek. Devonian.

k (non Hall), Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 309.

eek, note appended to extras of the paper mentioned above.—

can Nat., XXII, 1888, p. 1102.

eek, Simpson's Rep. Expl. Great Basin Terr. Utah, 1876, p.

reta) strigosa Meek, King's U. S. Geol. Expl. 40th Parl., IV, , fig. 5.

Utah; Nevada; Rockford, Iowa.

all. Warsaw (L. Carb.).

Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 663, pl. 23, fig.

. Rep. N. Y. State Geol., 1883, pl. 56, figs. 13, 14.—Hall and

w York, VIII, Pt. II, 1893, pp. 26, 36, pl. 31, figs. 13, 14.

ois.

Hall. Chemung and Marshall (Dev.-L. Carb.).

Owen, Rep. Geol. Survey Wisconsin, Iowa, and Minnesota, .

nata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 504, pl. 4, fig. 3.

ta A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. , Cont. Canadian Pal., I, 1891, p. 223.

and Buffalo, Iowa; Rock Island, Illinois; Naples, New York; r, Canada; in the Marshall group at Port aux Barques,

s Hall. Warsaw (L. Carb.).

mis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 660, pl. 23, fig. 6.

rmis White, Twelfth Ann. Rep. U. S. Geol. Survey Terr., 1883, g. 2.

; Spergen Hill, Indiana.

us Hall=Syringothyris texta.

Whiteaves. Hamilton (Dev.).

ata Whiteaves, Cont. Canadian Pal., I, 1889, p. 114, pl. 15,

Thames River, Canada.

McChesney=Spiriferina subelliptica.

Meek=Martinia sublineata.

tu Hall, 1858 (non 1857)=Spirifer subattenuatus.

Digitized by Google

Spirifer submucronatus Hall. Oriska

Spirifer submucronata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1
Pal. New York, III, 1859, p. 419, pl. 96, fig. 7.
Spirifera submucronata Hall, Second Ann. Rep. N. Y. State Geol.,
figs. 5–7.
Spirifer submucronatus Hall and Clarke, Pal. New York, VIII, Pt. II,
36, pl. 33, figs. 5–7.
Loc. Cumberland, Maryland.
Obs. Possibly the young of Spirifer cumberlandia.

Spirifer suborbicularis Hall. Keokuk (

Spirifer suborbicularis Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 64
Spirifera suborbicularis Meek and Worthen, Geol. Survey Illinois,
523, pl. 30, fig. 1.
Loc. Keokuk, Iowa; Warsaw and Nauvoo, Illinois.

Spirifer subrotundatus Hall. Kinderhook (

Spirifer subrotundata Hall (non McCoy, 1855), Geol. Survey Iowa, I,
p. 521, pl. 7, fig. 8.
Spirifera subrotundata Keyes, Geol. Survey Missouri, V, 1895, p. 78.
Loc. Burlington, Iowa; Sciotoville, Ohio (Winchell).
Obs. This specific name was first used by McCoy in 1855 but is usual
as a synonym for S. pinguis Sowerby. De Koninck, howe
McCoy's name as late as 1887.

Spirifer substrigosus Webster. Chemu

Spirifera substrigosa Webster, American Nat., XXII, 1888, p. 1101.
Loc. Near Rockford, Iowa.

Spirifer subsulcatus Hall. Ari

Spirifer subsulcata Hall (non Dalman, 1828), Canadian Nat. Geol.
145.
Spirifera subsulcata Dawson, Acadian Geology, 3d ed., 1878, p. 597.
American Geol. and Pal., 1889, p. 376.
Loc. Arisaig, Nova Scotia.

Spirifer subumbona Hall=Martinia subumbona.

Spirifer subundifera Meek and Worthen=Reticularia subund

Spirifer subvaricosus Hall and Whitfield. ? Hamilt

Spirifera subvaricosa Hall and Whitfield, Twenty-third Rep. N. Y
Nat. Hist., 1872, p. 237, pl. 11, figs. 12-15.
Loc. Waterloo, Iowa.

Spirifer subventricosus McChesney=Spirifer rockymontana.

Spirifer sulcatus Hall=Delthyris sulcata.

Spirifer sulcifer Shumard. Upper Carb

Spirifer sulcifera Shumard, Trans. St. Louis Acad. Sci., I, 1858, p.
fig. 3.
Loc. Guadalupe Mountains, New Mexico.

Spirifer superbus Billings (non Eichwald)=Spirifer billingsa

Spirifer taneyensis Swallow. Chouteau (

Spirifer taneyensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 6
Spirifera taneyensis Keyes. Geol. Survey Missouri, V, 1895, p. 78.
Loc. Taney County, Missouri.

Spirifer temeraria Miller=Reticularia temeraria.

Digitized by Google

Spirifer tenuicostatus Hall. Keokuk and Warsaw (L. Carb.).

Spirifer tenuicostata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 662, pl. 23, fig. 8.
Loc. Keokuk, Iowa; Warsaw and Dallas, Illinois.

Spirifer tenuimarginatus Hall. Keokuk (L. Carb.).

Spirifer tenuimarginata Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 641, pl. 20, fig. 1.
Spirifera tenuimarginata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 57, figs. 4–6.
Spirifer tenuimarginatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 38, pl. 32, figs. 4, 6.
Loc. Warsaw, Illinois.

Spirifer tenuis Hall. Hamilton (Dev.).

Spirifer tenuis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 162.
Spirifera tenuis Hall, Pal. New York, IV, 1867, p. 236.
Loc. Cumberland, Maryland.
Obs. Compare with Spirifer granulosus Conrad.

Spirifer tenuispinatus Herrick=Reticularia tenuispinata.

Spirifer tenuistriatus Shaler (non Hall)=Spirifer radiatus.

Spirifer tenuistriatus Hall. Lower Helderberg (Dev.).

Spirifer tenuistriata Hall, Pal. New York, III, 1859, p. 204, pl. 28, fig. 3.
Spirifera tenuistriata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 61, fig. 8.
Spirifer tenuistriatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 36, fig. 8.
Loc. Decatur County, Tennessee.

Spirifer texasanus Meek. Upper Carboniferous.

Spirifer (Trigonotreta?) texana Meek, Proc. Acad. Nat. Sci. Philadelphia, 1871, p. 179.
Spirifer (Trigonotreta?) texanus Meek, Macomb's Rep. Expl. Exped. from Santa Fe to the Great Colorado of the West, 1876, p. 139, pl. 3, fig. 5.
Spirifera multigranosa Worthen, Geol. Survey Illinois, VIII, 1890, p. 105, pl. 11, fig. 5.
Spirifer texanus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 26, 38, pl. 37, figs. 16, 17.
Loc. Young and Jack counties, Texas; Springfield, Illinois.

Spirifer textus Hall=Syringothyris texta.

Spirifer translatus Swallow=Reticularia translata.

Spirifer transversus McChesney=Spiriferina transversa.

Spirifer tribulis Hall. Oriskany (Dev.).

Spirifer tribulis Hall, Pal. New York, III, 1859, p. 420, pl. 96, fig. 8;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 58, figs. 1–4.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 19, 37, pl. 33, figs. 1–4.
Loc. Cumberland, Maryland.
Obs. Possibly the young of Spirifer murchisoni.

Spirifer trigonalis (Martin). Carboniferous.

Anomites trigonalis Martin, Petrefacta Derbiensia, tab. 36, 1809, fig. 1.
Spirifera trigonalis Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 215, pl. 18, fig. 11.
Loc. Europe; Eureka district, Nevada.

Spirifer triplicatus Hall=Spirifer camaratus.

Spirifer triradialis Meek (non Phillips)=Spirifer agelaius.

Digitized by Google

Spirifer troosti Castelnau. ?Formation.

Spirifer troosti Castelnau, Essai Système Silurien l'Amérique Septentrionale, 1843, p. 41, pl. 12, fig. 5.

Loc. "Kentucky."

Spirifer tullius Hall. Hamilton (Dev.).

Spirifera tullia Hall, Pal. New York, IV, 1867, p. 218, pl. 35, figs. 1-9;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 52, fig. 18.

Spirifera tullia var. Whiteaves, Cont. Canadian Pal., I, 1891, p. 224, pl. 32, fig. 1.

Spirifer tullius Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 14, 35, pl. 22, fig. 18; pl. 37, figs. 6, 7.

Loc. Tully, Apulia, etc., New York; Athabasca River, Canada.

Spirifer tumidus Bayle and Coquand=Spiriferina rostrata.

Spirifer undiferus Roemer=Reticularia undifera.

Spirifer unica Hall=Spirifer arenosus.

Spirifer urbanus Calvin. Hamilton (Dev.).

Spirifera urbana Calvin, Bull. Lab. Univ. of Iowa, 1888, p. 28.—Bull. Lab. Nat. Hist. State Univ. Iowa, II, 1892, p. 166, pl. 12, fig. 1.

Loc. Iowa City and Linn County, Iowa.

Spirifer utahensis Meek=Cyrtia norwoodi.

Spirifer valenteana Rathbun. Middle Devonian.

Spirifera valenteana (Hartt MS.) Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 241, pl. 8, fig. 11.

Loc. Erere, Province of Para, Brazil.

Spirifer vanuxemi Hall. Tentaculite (Sil.).

Orthis plicata Vanuxem (non Sowerby), Geol. New York; Rep. Third Dist., 1842, p. 112, fig. 1.

Orthis? (Delthyris) plicatus Hall, Ibidem, Fourth Dist., 1843, p. 142, fig. 1.

Spirifer vanuxemi Hall, Pal. New York, III, 1859, p. 198, pl. 8, figs. 17-23;—Second Rep. N. Y. State Geol., 1883, pl. 61, fig. 11.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 19, 36, pl. 36, fig. 11.—Whitfield, Geol. Ohio, VII, 1895, p. 411, pl. 1, figs. 4, 5.

Spirifera vanuxemi Whitfield, Annals N. Y. Acad. Sci., V, 1891, p. 509, pl. 5, figs. 4, 5.

Loc. Albany and Schoharie counties, New York; Put in Bay Island, Lake Erie.

Obs. Vanuxem's specific name is restored, since Sowerby's species is an Orthis.

Spirifer varicosus Hall. Corniferous (Dev.).

Spirifer varicosa Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 130.

Spirifera varicosa Billings, Canadian Jour., VI, 1861, p. 255, figs. 63, 64;—Geol. Canada, 1863, p. 960, fig. 467.—Hall, Pal. New York, IV, 1867, p. 205, pl. 31, figs. 1-4;—Second Rep. N. Y. State Geol., 1883, pl. 59, figs. 4-8.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 136.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 134, pl. 10, figs. 11-20, 23-25.

Spirifer varicosus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 17, 36, pl. 34, figs. 4-8.

Loc. Williamsville, New York; Woodstock, Canada; Columbus, Ohio; Louisville, Kentucky; Eureka district, Nevada.

Spirifer ventricosa Hall=Nucleospira ventricosa.

Spirifer venustus Hall=Spirifer divaricatus.

Spirifer vernonensis Swallow. Chouteau (L. Carb.).

Spirifer vernonensis Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 644.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 119.

Loc. St. Louis County, Missouri.

Obs. Regarded by Keyes as a synonym for S. marionensis.

Digitized by Google

arkensis Swallow. Chouteau (L. Carb.).
var. ozarkensis Swallow, Trans. St. Louis Acad. Sci., I, 1860,

Missouri.
eyes as a synonym for S. marionensis.

mmon. Middle Devonian.
Ammon, Zeits. Gesell. für Erdk., Berlin, XXVIII, 1893, p.

ato Grosso, Brazil.

s Miller and Dyer=Mimulus waldronensis.

A. Winchell. Waverly (L. Carb.).
s A. Winchell, Proc. Amer. Phil. Soc., XII, 1870, p. 251.
" (A. Winchell's MS.).

l. Chemung (Dev.).
all, Geol. Survey Iowa, I, Pt. II, 1858, p. 502, pl. 4, fig. 2.—
, Pal. New York, VIII, Pt. II, 1893, pp. 24, 57, pl. 30, figs. 18, 19.
Hall, Pal. New York, IV, 1867, pp. 243, 417;—Second Rep.
., 1883, pl. 55, figs. 18, 19.—Tschernyschew, Mém. du Comité
ersbourg, III, 1887, p. 60.
a; North Saskatchewan, Canada; Russia.

l and Clarke. Chemung (Dev.).
all and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 361, pl.

ty, New York.

rrick. Waverly (L. Carb.).
Herrick, Bull. Denison Univ., III, 1888, p. 46, pl. 5, figs. 2, 3;
eol. Ohio, VII, 1895, pl. 21, figs. 2, 3.
.

Schuchert. Oriskany (Dev.).
i Meek and Worthen (non Meek, 1860), Geol. Survey Illinois,
pl. 8, fig. 5.
Meek (non Hall, 1857), King's U. S. Geol. Expl. 40th Parl., IV,

a Schuchert, Ninth Ann. Rep. N. Y. State Geol., 1890, p. 54.
Illinois.

eek (non Hall)=Spirifer worthenanus.

l. Hamilton (Dev.).
all, Tenth Rep., N. Y. State Cab. Nat. Hist., 1857, p. 156.—
, Pal. New York, VIII, Pt. II, 1895, pl. 27, figs. 19, 20.
y, Illinois.

(non Roemer)=Delthyris consobrina.

igny.

pe Spirifer walcotti Sowerby=S. rostrata (Schlot-
m).
y, Paris Acad. Sci., Comptes Rendus, XXV, 1847, p. 268;—
XIII, 1850, p. 334.—White, Proc. Boston Soc. Nat. Hist., IX,
agen, Palæontologica Indica, Ser. XIII, I, 1883, p. 498.—Hall
. New York, VIII, Pt. II, 1893, p. 51;—Thirteenth Ann. Rep.
logist, 1895, p. 764.

Digitized by Google

Spiriferina aciculifera (Rowley). Kinderhook (L. Carb.).

Spirifera aciculifera Rowley, American Geologist, XII, 1893, p. 307;—Ibidem, 1893, pl. 14, figs. 13, 14.

Loc. Louisiana, Missouri.

Spiriferina (?) alia Hall and Whitfield. Triassic.

Spirifera (Spiriferina?) alia Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 281, pl. 6, fig. 17.

Loc. Dun Glen Pass, Pah-Ute Range, Nevada.

Spiriferina billingsi Shumard. Upper Carboniferous.

Spiriferina billingsi Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 294, 391.

Loc. Guadalupe Mountains, New Mexico and Texas.

Spiriferina binacuta A. Winchell. Burlington (L. Carb.).

Spiriferina binacuta A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 120.

Loc. Burlington, Iowa.

Spiriferina borealis Whiteaves. Triassic.

Spiriferina borealis Whiteaves, Cont. Canadian Pal., I, 1888, p. 128, pl. 17, fig. 1, abstract.

Loc. Liard River, Canada.

Spiriferina clarksvillensis A. Winchell. Chouteau (L. Carb.).

Spiriferina clarksvillensis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 119.—Keyes, Geol. Survey Missouri, V, 1895, p. 85.

Loc. Clarksville, Missouri.

Spiriferina cristata Walcott=S. spinosa.

Spiriferina cristata (Schlotheim). Upper Carboniferous.

Terebratulites cristatus Schlotheim, Beit. zur Naturg. der Verst.; Akad. der Wiss. zu München, 1816, pl. 1, fig. 3.

Spirifer octoplicata? Hall (non Sowerby), Stansbury's Exped. Great Salt Lake of Utah, 1852, p. 409, pl. 4, fig. 4.

Spirifer kentuckyensis Shumard, Geol. Survey Missouri, I, 1855, p. 203.—Hall, Pacific Railroad Rep., III, 1856, p. 102, pl. 2, figs. 10, 11.—Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p. 27.

Spiriferina cristata Davidson, Quart. Jour. Geol. Soc. London, 1863, p. 170, pl. 9, fig. 6.—Dawson, Acadian Geol., 3d ed., 1878, p. 291, fig. 90.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 218, pl. 18, figs. 12, 13.—Smith, Proc. American Phil. Soc., XXV, 1897, p. 32.

Spirifer laminosus Geinitz (non McCoy), Carb. und Dyas in Nebraska, 1866, p. 45, pl. 3, fig. 19.

Spirifer kentuckyensis var. propatulus Swallow, Trans. St. Louis Acad. Sci., II, 1866, p. 489.

?Spiriferina octoplicata Toula, Sitzungsb. der kais. Akad. der Wissensch. zu Wien, LIX, 1869, p. 5.

Spiriferina kentuckyensis Meek, Final Rep. U. S. Geol. Survey of Nebraska, 1872, p. 185, pl. 6, fig. 3; pl. 8, fig. 11.—White, Wheeler's Expl. and Survey west 100th Meridian, IV, 1875, p. 138, pl. 10, fig. 4;—Thirteenth Rep. Indiana State Geol., 1884, p. 135, pl. 35, figs. 13, 14.—Keyes, Proc. Acad. Nat. Sci. Philadelphia, 1890, p. 231.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 52, fig. 41, pl. 29, fig. 17.—Keyes, Geol. Survey Missouri, V, 1895, p. 86.

Spiriferina cristata? Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 629.

Spirifer (Spiriferina) kentuckyensis Hall, Second Rep. N. Y. State Geol., 1883, pl. 61, figs. 14–16.

Digitized by Google

Spiriferina cristata (Schlotheim)—Continued.

Loc. Europe; Kentucky; Indiana; Illinois; Missouri; Iowa; Kansas; Arkansas; Nebraska; Texas; New Mexico; Utah; Arizona; Nevada; Nova Scotia; Cape Joseph Henry, lat. 82° 43′; near Cochabamba, Bolivia.

Obs. See Spiriferina octoplicata and S. norwoodana.

Spiriferina depressa Herrick. Waverly (L. Carb.).

Spiriferina depressa Herrick, Bull. Denison Univ., III, 1888, p. 47, pl. 10, fig. 3.

Loc. Near Granville, Ohio.

Spiriferina gonionotus Meek. Upper Carboniferous.

Spiriferina sp. undet. Meek, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 84, pl. 8, fig. 5.

Spiriferina gonionota Meek, Ibidem, 1877, at end of description.

Loc. Diamond Mountains, Nevada.

Obs. Compare with Spiriferina laminosa (McCoy).

Spiriferina homfrayi (Gabb). Triassic.

Spirifer ? homfrayi Gabb, Geol. Survey California, Pal., I, 1864, p. 35, pl. 6, fig. 38.

Spiriferina homfrayi Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 281, pl. 6, fig. 18.

Loc. Star Canyon, Humboldt County, Nevada; Dun Glen Pass, Pah-Ute Range, Nevada.

Spiriferina kentuckyensis Shumard=Spiriferina cristata.

Spiriferina kentuckyensis propatula Swallow=Spiriferina cristata.

Spiriferina cfr. munsteri Davidson. Jurassic.

Spiriferina cf. munsteri (Dav.) Möricke, Neues Jahrbuch f. Mineral., Beilageband, IX, 1894, p. 60.

Loc. Europe; Cordillere of Copiapo, Chile.

Spiriferina norwoodana (Hall). Warsaw (L. Carb.).

Spirifer norwoodana Hall, Trans. Albany Inst., IV, 1858, p. 7.

Spiriferina norwoodana Whitfield, American Mus. Nat. Hist., I, 1882, p. 48, pl. 6, figs. 16, 17.—Hall, Twelfth Rep. State Geol. Indiana, 1883, p. 327, pl. 29, figs. 16, 17.

Loc. Spergen Hill, Indiana; Alton, Illinois; Princeton, Kentucky.

Obs. Probably identical with Spiriferina cristata.

Spiriferina obtusa (Gabb). Triassic.

Spirifer obtusus Gabb, American Jour. Conch., V, 1870, p. 17, pl. 7, fig. 16.

Loc. "Volcano," Nevada.

Spiriferina octoplicata (Sowerby). Upper Carboniferous.

Spirifer octoplicata Sowerby, Mineral Conch., 1827, p. 120, pl. 562, figs. 2–4.

Spiriferina cristata var. octoplicata Davidson, Mon. British Carb. Brach., Pal. Soc., 1857, p. 38, pl. 7, figs. 37–47.

Spiriferina spinosa var. campestris White, Wheeler's Expl. and Survey west 100th Merid., Prel. Rep., 1874, p. 21.

Spiriferina octoplicata White, Ibidem, Final Rep., 1875, p. 139, pl. 10, fig. 8.

Loc. Europe; Santa Fe, New Mexico; northern Colorado; Lincoln County, Nevada.

Obs. Probably identical with Spiriferina cristata.

Spiriferina pulchra Meek. Upper Carboniferous.

Spirifera pulchra Meek, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 310.

Spiriferina pulchra Meek, Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 1864, 172, p. 19;—King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 85, pl. 8, fig. 1; pl. 12, fig. 12.

Digitized by Google

Spiriferina pulchra Meek—Continued.

Spirifer (Spiriferina) pulcher, Meek. Simpson's Rep. Expl. Great Basin Torr. Utah, 1876, p. 352, pl. 2, fig. 1.

Loc. White Pine district, Nevada; Long and Ruby valleys, Utah.

Spiriferina rostrata Schlotheim. Jurassic.

Spirifer chilensis Forbes, Darwin's Geol. Observations S. America, 1846, p. 267, pl. 5, figs. 15, 16.

Spirifer linguiferoides Forbes, Ibidem, 1846, p. 267, pl. 5, figs. 17, 18.

Spirifer tumidus Bayle and Coquand, Mém. Géol. Soc. France, ser. ii, IV, 1851, p. 19, pl. 7, figs. 11, 12.

Spirifer chilensis and rostratus Burmeister and Geibel, Abh. Naturf. Gesell. Halle, VI, 1862, p. 125.

Spiriferina rostrata (Schl.) Möricke, Neues Jahrb. f. Mineral., Beilageband, IX, 1894, p. 59.

Loc. Europe; Sierra de la Ternera, Las Amolanes, Rio Claro, Tres Cruces, Manfias, Cordillera de Guasco, and Juntas, Chile.

Spiriferina solidirostris White. Kinderhook (L. Carb.).

Spirifer solidirostris White, Jour. Boston Soc. Nat. Hist., VII, 1860, p. 232.

Spiriferina solidirostris White, Ibidem, IX, 1862, p. 24.—A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 120.—Herrick, Bull. Denison Univ., III, 1888, p. 47, pl. 2, figs. 9–11; pl. 5, fig. 13;—Geol. Ohio, VII, 1895, pl. 21, fig. 13.

Loc. Burlington, Iowa; Hamburg, Illinois; Newark and Sciotoville, Ohio.

Spiriferina spinosa (Norwood and Pratten). Kaskaskia (L. Carb.).

Spirifer spinosa Norwood and Pratten, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., III, 1856, p. 71, pl. 9, fig. 1.—Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 706, pl. 27, fig. 5.

Spiriferina spinosa? Derby, Bull. Cornell Univ., I, 1874, p. 23, pl. 6, figs. 8, 13, 14.

Spiriferina spinosa Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 60, figs. 26–29.

Spiriferina cristata Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 218, pl. 18, figs. 12, 13.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 52–54, pl. 35, figs. 26–29.

? Spiriferina spinosa Herrick, Bull. Geol. Soc. America, II, 1891, p. 46, pl. 1, fig. 19.

Loc. Kaskaskia, Alton, and Chester, Illinois; Bloomington, Indiana; Crittenden County, Kentucky; Itaituba, Brazil.

Spiriferina spinosa campestris White=Spiriferina octoplicata.

Spiriferina subelliptica (McChesney). Keokuk (L. Carb.).

Spirifer subelliptica McChesney, New Pal. Fossils, 1860, p. 43.

Spiriferina subelliptica Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 54, pl. 35, figs. 21, 22.

Loc. Buttonmould Knob, Kentucky; New Providence, Indiana.

Spiriferina subtexta White. Burlington (L. Carb.).

Spiriferina ? subtexta White, Proc. Boston Soc. Nat. Hist., IX, 1862, p. 25.

Loc. Burlington, Iowa.

Spiriferina transversa (McChesney). Kaskaskia (L. Carb.).

Spirifer transversa McChesney, New Pal. Fossils, 1860, p. 42;—Trans. Chicago Acad. Sci., I, 1868, p. 34, pl. 6, fig. 3.—Hall, Second Rep. N. Y. State Geol., 1883, pl. 60, figs. 19–22.

Digitized by Google

sversa (McChesney)—Continued.
ansversa Derby, Bull. Cornell Univ., I, 1874, p. 21, pl. 2, figs. 4, 5,
13, figs. 12–14, 17; pl. 5, fig. 4.—Hall and Clarke, Pal. New York,
II, 1893, pp. 46, 64, pl. 35, figs. 19, 20, 23–25.
s Roost, Alabama; Litchfield, Kentucky; Bomjardim and Itaituba,

bigny=Athyris.
ea A. Winchell=Athyris fultonensis.
osulcata White (non Phillips)=Cleiothyris crassicardi-

A Waagen. Genotype S. derbyi Waagen.
Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 450.—Hall and
al. New York, VIII, Pt. II, 1893, p. 98;—Thirteenth Ann. Rep. N. Y.
logist, 1895, p. 782.
byi Waagen. Upper Carboniferous.
lita (partim) Derby, Bull. Cornell Univ., I, 1874, p. 7, pl. 1, fig. 7
other figures).
derbyi Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 453, pl.
4–7, 9–13; pl. 37, figs. 11–13.—Hall and Clarke, Pal. New York,
II, 1893, p. 99, fig. 73.
im and Itaituba, Brazil.
Ehlert (non Conrad or Hall)=Camarophoria.
. Conrad. Genotype Terebratulites schlotheimii Conrad
(non von Buch)=Rhynchonella formosa Hall.
onrad, Second Ann. Rep. N. Y. Geol. Survey, 1839, pp. 58, 59.—
Hayden (partim), Pal. Upper Missouri, Smithsonian Cont. to Knowl.,
1864, p. 16, footnote.—Hall, Pal. New York, IV, 1867, pp. 334, 335.—
Palæontologica Indica, Ser. XIII, I, 1883, pp. 411, 431, 436.—Miller,
can Geol. and Pal., 1890, p. 337.—Hall and Clarke, Pal. New York,
II, 1893, p. 187;—Thirteenth Ann. Rep. N. Y. State Geol., 1895, p. 826.
ve synonymy is retained for historical purposes. The only species
e genus by Hall and Clarke is the type species, Rhynchonella for-
ich seems to be nothing more than a Rhynchotrema. This will
nochisma without a species. This name, however, should not dis-
er Rhynchotrema or Camarotœchia, since it was not defined, and in
to this was founded by Conrad upon an erroneous identification.
he view of Œhlert be adopted, i. e., that Stenochisma should dis-
narophoria King, because Conrad gave as the type C. schlotheimii.
e did not apply to von Buch's species, but to the shell now known
honella formosa Hall.
s formerly referred to Stenochisma will be found under Camarotœ-
pt R. formosa, which is referred to Rhynchotrema.
ll, 1857 (non Conrad, 1839, Hall, 1867)=Zygospira.
idson. Genotype Terebratula grayi Davidson.
dson, Geol. Mag., VIII, 1881, p. 150, pl. v, fig. 13.—Hall and Clarke,
York, VIII, Pt. I, 1892, p. 274;—Eleventh Ann. Rep. N. Y. State
, 1894, p. 289.
avidson. Niagara (Sil.).
rayii Davidson, Bull. Soc. Géol. France, 2d ser., V, 1848, p. 331, pl.

Digitized by Google

Streptis grayi Davidson—Continued.

Atrypa? grayi Davidson, British Sil. Brach., Paleontographical Soc. (1866), 1867, p. 141, pl. xiii, figs. 14–22.

Streptis grayi Williams, American Jour. Sci., 3d ser., XLVIII, 1894, p. 331.

Loc. England; Batesville, Arkansas.

Streptis waldronensis Beecher and Clarke=Mimulus waldronensis.

STREPTORHYNCHUS King.

Genotype Terebratulites pelargonatus Schlotheim.

Streptorhynchus King, Mon. Permian Fossils, Pal. Soc., 1850, p. 107.—Derby (partim), Bull. Cornell Univ., I, 1874, pp. 32, 39.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 267;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 288.

Streptorhynchus æquivalvis Hall=Orthothetes inæqualis.

Streptorhynchus agassizi Rathbun=Orthothetes agassizi.

Streptorhynchus approximata James=Strophomena approximata.

Streptorhynchus arctostriata Walcott=Orthothetes chemungensis arctistriatus.

Streptorhynchus biloba Hall=Derbya biloba.

Streptorhynchus cardinale Whitfield=Strophomena cardinalis.

Streptorhynchus chemungensis Hall=Orthothetes chemungensis.

Streptorhynchus coreanus Derby=Derbya correana.

Streptorhynchus crenistria Keyes (non Phillips)=Derbya crassa.

Streptorhynchus crenistrius American authors=Orthothetes crenistria.

Streptorhynchus elongatus James=Strophomena rugosa.

Streptorhynchus filitextus Hall=Strophomena incurvata.

Streptorhynchus flabellum Whitfield=Orthothetes flabellum.

Streptorhynchus hallianus Derby. Upper Carboniferous.

Streptorhynchus hallianus Derby, Bull. Cornell Univ., I, 1874, p. 35, pl. 5, figs. 1, 2, 5, 8, 12, 14, 16, 18; pl. 8, fig. 3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 268, pl. 11, figs. 6–17.

Loc. Bomjardim and Itaituba, Brazil.

Streptorhynchus hallanum Miller=Strophomena halli.

Streptorhynchus hemiaster Winchell and Marcy=Orthothetes subplanus.

Streptorhynchus hydraulicum Whitfield=Orthothetes hydraulicus.

Streptorhynchus inæqualis Winchell=Orthothetes inæqualis.

Streptorhynchus inflatus White and Whitfield=Orthothetes inflatus.

Streptorhynchus lens White=Orthothetes lens.

Streptorhynchus minor Walcott=Strophomena minor.

Streptorhynchus (?) multistriata (Meek and Hayden).

Upper Carboniferous.

Orthisina umbraculum? Meek and Hayden, Proc. Acad. Nat. Sci. Philadelphia, 1859, p. 26.

Orthisina multistriata Meek and Hayden, Ibidem, 1859, at end of description.

Loc. Fort Riley, Kansas.

Streptorhynchus neglectus James=Strophomena neglecta.

Streptorhynchus occidentalis Newberry=Meekella occidentalis.

Digitized by Google

ius pandora Billings=Orthothetes pandora.
ius perversus=Orthothetes chemungensis perversus.
ius planoconvexus Hall=Strophomena planiconvexa.
ius planumbonus Hall=Strophomena rugosa.
ius primordiale Whitfield=Billingsella primordialis.
ius pyramidalis Newberry=Meekella pyramidalis.
ius robusta Hall=Derbya robusta.
ius subplanus Hall=Orthothetes subplanus.
ius subsulcatum Sardeson=Strophomena scofieldi.
ius subtenta Hall, 1883=Strophomena trentonensis.
ius tapajotensis Derby=Orthothetes tapajotensis.
ius tenuis Hall=Orthothetes tenuis.
s ulrichi Hall and Clarke. Kaskaskia (L. Carb.).
hus ulrichi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp.
pl. 11B, fig. 15.
den County, Kentucky.
ius umbraculum Winchell=Orthothetes umbraculum.
ius vetusta James=Strophomena vetusta.
ius woolworthianus Hall=Orthothetes woolworthianus.
Billings=Stricklandinia.
rachne Billings=Syntrophia arachne.
rethusa Billings=Syntrophia arethusa.
NIA Billings. Genotype Stricklandia gaspensis Bill.
Billings, Canadian Nat. and Geol., IV, 1859, p. 132;—Canadian
VI, 1861, p. 265;—Pal. Fossils, I, 1862, p. 84;—Proc. Portland Soc.
t., 1863, p. 114.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883,
ia Billings, Canadian Nat. and Geol., VIII, 1863, p. 370.—Hall, Twen-
p. N. Y. State Cab. Nat. Hist., 1867, p. 160;—Pal. New York, IV,
69.—Billings, Pal. Fossils, II, 1874, p. 78.—Nettelroth, Kentucky
nells, Mem. Kentucky Geol. Survey, 1889, p. 64.—Hall and Clarke,
York, VIII, Pt. II, 1893, p. 249;—Thirteenth Ann. Rep. N. Y. State
t, 1895, p. 847.
nticostiensis Billings. Anticosti (Sil.).
ia anticostiensis Billings, Canadian Nat. and Geol., VIII, 1863, p.
ll and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251, pl. 73,
4.
ti.
billingsana Dawson. Arisaig (Sil.).
ia billingsiana Dawson, Canadian Nat. and Geol., 2d ser., IX, 1880,
cotia.
brevis Billings. Anticosti (Sil.).
cies? Hall, Pal. New York, II, 1852, p. 66, pl. 22, fig. 3.
brevis Billings, Canadian Nat. and Geol., IV, 1859, p. 135.
ia brevis Billings, Pal. Fossils, II, 1874, p. 84, pl. 6, fig. 2.—Hall
ke, Pal. New York, VIII, Pt. II, 1893, p. 251.
ti; ?Sodus, Wayne County, New York.

Digitized by Google

Stricklandinia canadaensis Billings. Clinton (Sil.).

Stricklandia canadensis Billings, Canadian Nat. and Geol., IV, 1859, p. 135.

Stricklandinia canadensis Billings, Pal. Fossils, II, 1874, p. 81.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251.

Loc. Near Thorold, Ontario.

Stricklandinia castellana White. Niagara (Sil.).

Stricklandinia castellana White, Proc. Acad. Nat. Sci. Philadelphia, 1876, p. 30.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251, pl. 73, figs. 3–7.

Loc. Castle Grove, Jones County, Iowa.

Stricklandinia chapmani Hall and Clarke. Niagara (Sil.).

Stricklandinia chapmani Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 83, fig. 40.

Loc. Hamilton, Ontario.

Stricklandinia davidsoni Billings. Anticosti (Sil.).

Stricklandinia davidsoni Billings, Geol. Mag., V, 1868, p. 59, pl. 4, figs. 1–1*d*;—Pal. Fossils, II, 1874, p. 86, pl. 6, fig. 1.—White, Proc. U. S. Nat. Mus., III, 1880, p. 48.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251, pl. 73, fig. 15.

Loc. Anticosti; eastern Canada; Ringgold, Catoosa County, Georgia.

Stricklandinia deformis Meek and Worthen. Niagara (Sil.).

Stricklandinia deformis Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1870, p. 37;—Geol. Survey Illinois, VI, 1875, p. 502, pl. 24, fig. 5.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251, pl. 73, figs. 8–10.

Loc. Carroll County, Illinois.

Obs. Probably the same as S. melissa.

Stricklandinia elongata Billings=Amphigenia elongata.

Stricklandinia elongata curta Meek and Worthen=Amphigenia curta.

Stricklandinia gaspiensis Billings. Gaspé (Sil.).

Stricklandia gaspiensis Billings, Canadian Nat. and Geol., IV, 1859, p. 134.

Stricklandinia gaspiensis Billings, Pal. Fossils, II, 1874, p. 83, fig. 49;—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251, pl. 73, fig. 11.

Loc. Bay of Chaleurs, Canada.

Stricklandinia lens (Sowerby). Silurian.

Atrypa lens Sowerby, Murchison's Silurian System, 1839, pl. 21, fig. 3.

Stricklandinia lens Billings, Catalogue Sil. Foss. Anticosti, 1866, p. 45.—Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 321, pl. 5, figs. 1–4.

Loc. England; Anticosti; Collinsville, Alabama.

Stricklandinia lirata (Sowerby). Anticosti (Sil.).

Spirifer liratus Sowerby, Murchison's Silurian System, 1839, pl. 22. fig. 6.

Stricklandinia lirata Davidson, Mon. British Sil. Brach., Pal. Soc., 1867, p. 159, pl. 20, figs. 1–13.—Billings, Cat. Sil. Foss. Anticosti, 1866, p. 45.

Loc. Europe; Anticosti.

Stricklandinia (?) louisvillensis Nettelroth. Niagara (Sil.).

Stricklandinia louisvillensis Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 65, pl. 34, figs. 31–34.

Loc. East of Louisville, Kentucky.

Stricklandinia melissa Billings. Anticosti (Sil.).

Stricklandinia melissa Billings, Pal. Fossils, II, 1874, p. 89, pl. 7, fig. 4.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251.

Loc. Anticosti.

Obs. Probably the same as S. deformis.

Digitized by Google

ltilirata Whitfield. Guelph (Sil.).
multilirata Whitfield, Ann. Rep. Geol. Survey Wisconsin, 1877,
l. Wisconsin, IV, 1882, p. 315, pl. 23, figs. 3–5.—Hall and Clarke,
ork, VIII, Pt. II, 1893, p. 251, pl. 73, figs. 1, 2.
, Wisconsin.

teri Billings. Anticosti (Sil.).
salteri Billings, Geol. Mag., V, 1868, p. 61, pl. 4, figs. 2–2*a*;—Pal.
1874, p. 87, pl. 7, fig. 1.—White, Proc. U. S. Nat. Mus., III, 1880,
and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 251.
Ringgold, Catoosa County, Georgia.

subquadrata Herrick. Upper Carboniferous.
? subquadrata Herrick, Bull. Denison Univ., II, 1887, p. 49, pl. 1,

e, near Newark, Ohio.
a terebratuloid.

plesiana Foerste. Clinton (Sil.).
triplesiana Foerste, Bull. Denison Univ., I, 1885, p. 89, pl. 14,
—Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 323;—Geol. Ohio,
. 594, pl. 26, figs. 13, 14.
hio.

LUS Defrance. Genotype S. burtini Defrance.
Defrance, Dict. Sci. Nat., LI, 1827, p. 102, pl. 75, fig. 1.
s Sandberger, Leonhard und Bronn's Jahrb. für Min., 1842, p.
American Jour. Conch., VI, 1870, p. 112.—Hall and Clarke, Pal.
VIII, Pt. II, 1893, p. 282, figs. 203–207.

urtoni Defrance. Middle Devonian.
burtoni Defrance, Dict. Sci. Nat., LI, 1827, p. 102, pl. 75, fig. 1.
s burtoni Whiteaves, Trans. Royal Soc. Canada, VIII, 1891, p. 93;—
nadian Pal., I, 1891, p. 235, pl. 29, figs. 10–11; p. 290.—Hall and
. New York, VIII, Pt. II, 1893, p. 283, fig. 203.
Lakes Manitoba and Winnipegosis and the "Ramparts," Macken-
British America. Two loose specimens have been found near
ocks in southern Minnesota.

King. Genotype Orthis excavata Geinitz.
ng, Ann. and Mag. Nat. Hist., XIV, 1844, p. 313;—Ibidem, XVII,
—Mon. Permian Fossils, Pal. Soc., 1850, p. 93.—Hall, Twentieth
State Cab. Nat. Hist., 1867, p. 245;—Pal. New York, IV, 1867, p.
ner, American Jour. Sci., 3d ser., XL, 1890, p. 240.—Hall and Clarke,
York, VIII, Pt. I, 1892, p. 314;—Eleventh Ann. Rep. N. Y. State
1894, p. 295.

neri Rowley. Kinderhook (L. Carb.).
eecheri Rowley, American Geologist, XII, 1893, p. 308, pl. 14,

, Missouri.

elliana Derby. Upper Carboniferous.
ornelliana Derby, Bull. Cornell Univ., I, 1874, p. 45, pl. 3, figs.
, 35–38; pl. 4, fig. 5; pl. 8, fig. 17; pl. 9, figs. 10, 11.—Hall and
. New York, VIII, Pt. I, 1892, pl. 15B, figs. 36, 37.
n, Brazil.

bula Hall and Clarke. Keokuk (L. Carb.).
mbula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17A,
9.
sville and Lebanon, Kentucky.

Digitized by Google

Strophalosia (?) guadalupensis (Shumard). Upper Carboniferous.

Aulosteges guadalupensis Shumard, Trans. St. Louis Acad. Sci., I, 1858, p. 292, pl. 11, fig. 5; p. 390.

Strophalosia ? guadalupensis Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 241.

Loc. Guadalupe Mountains, New Mexico and Texas.

Strophalosia horrescens Geinitz (non Murchison, de Verneuil, and Keyserling)=Productus nebraskaensis.

Strophalosia hystricula Hall. Chemung (Dev.).

Productella hystricula Hall, Pal. New York, IV, 1867, p. 178, pl. 26, figs. 1–8;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 48, figs. 29, 30.

Strophalosia hystricula Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 316, pl. 15B, fig. 31; pl. 17, figs. 29, 30.

Loc. Forestville, Conewango, and East Randolph, New York.

Strophalosia keokuk Beecher. Keokuk (L. Carb.).

Strophalosia keokuk Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 244, pl. 9, figs. 18–24.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 316, pl. 17A, figs. 5–7.

Loc. Keokuk, Iowa.

Strophalosia muricata (Hall). Chemung (Dev.).

Chonetes muricata Hall, Pal. New York, IV, 1867, p. 143, pl. 22, figs. 29–43.

Chonetes (Productella?) muricata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 47, figs. 12, 16, 30, 38, 42.

Strophalosia? muricata Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 241.

Strophalosia muricata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 316, pl. 16, figs. 12, 16, 30, 38, 42.

Loc. Ellington, New York, and Meadville, Pennsylvania.

Strophalosia nummulina A. Winchell. Kinderhook (L. Carb.).

Strophalosia? nummularis A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 4.

Strophalosia? nummulina Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 242.

Strophalosia nummularis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 316.

Loc. Burlington, Iowa.

Strophalosia radicans (A. Winchell). Hamilton (Dev.).

Crania radicans A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 92.

Strophalosia radicans Beecher, American Jour. Sci., 3d ser., XL, 1890, pp. 240, 243, pl. 9, figs. 14–17.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 316, pl. 15B, figs. 27–30.

Loc. Grand Traverse region, Michigan.

Strophalosia rockfordensis Hall and Clarke. Upper Devonian.

Strophalosia rockfordensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 316, 353, pl. 17A, figs. 1–3; Pt. II, 1895, pl. 84, figs. 20–22.

Loc. Rockford, Iowa.

Strophalosia scintilla Beecher. Chouteau (L. Carb.).

Strophalosia scintilla Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 243, pl. 9, figs. 10–13.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 316, pl. 15B, figs. 32–34.

Loc. Pike County, Missouri.

Strophalosia spondyliformis (White and St. John). Upper Carboniferous.

Aulosteges spondyliformis White and St. John, Trans. Chicago Acad. Sci., I, 1868, p. 118, fig. 2.

Digitized by Google

lyliformis (White and St. John)—Continued.
ondyliformis Beecher, American Jour. Sci., 3d ser., XL, 1890,
ll and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 17A, figs.

and Pottawattamie counties, Iowa.

cata (Hall). Hamilton, Portage, and Ithaca (Dev.).
ustulosa Hall (non Productus pustulosus Phillips), Geol. N. Y.;
h Dist., 1843, p. 189, fig. 4.
catus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 171.
ncata Hall, Pal. New York, IV, 1867, p. 160, pl. 23, figs. 12–24;—
n. Rep. N. Y. State Geol., 1883, pl. 48, figs. 10–15.—Kindle, Bull.
al., 6, 1896, p. 35.
truncatus Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 131,
2.
trophalosia?) truncata Whiteaves, Cont. Canadian Pal., I, 1889,
6, figs. 1, 2.
uncata Beecher, American Jour. Sci., 3d ser., XL, 1890, p. 247—
larke, Pal. New York, VIII, Pt. I, 1892, p. 316, pl. 15B, figs. 24–26;
10–15.
; Thedford, Ontario; Eureka district, Nevada.

TA Hall. Genotype Strophomena demissa Conrad.
Hall, Pal. New York, II, 1852, p. 63.—Hall and Clarke, Pal. New
Pt. I, 1892, p. 284.
Hall, Geol. Survey Iowa, I, 1858, p. 491.—Billings, Canadian Jour.
n. ser., VI, 1861, p. 332;—Proc. Portland Soc. Nat. Hist., 1863, p.
Pal. New York, IV, 1867, p. 78.—Nettelroth, Kentucky Fossil
n. Kentucky Geol. Survey, 1889, p. 142.
haler, Bull. Mus. Comp. Zool., 4, 1865, p. 63.
nd Douvilina Hall and Clarke, Pal. New York, VIII, Pt. I, 1892,
6, 288, 289, 292; Eleventh Ann. Rep. N. Y. State Geologist, 1894,
1.

anthoptera (Whiteaves). Upper Silurian.
acanthoptera Whiteaves, Canadian Rec. Sci., 1891, p. 294, pl. 3,

f Saskatchewan and Lake Winnipegosis, Canada.

veata Hall. Upper Helderberg (Dev.).
alveata Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p.
New York, IV, 1867, p. 81, pl. 11, figs. 1–3.
ounty, New York.

cuata Hall. Chemung (Dev.).
arcuata Hall, Geol. Survey Iowa, I, 1858, p. 492, pl. 3, figs. 1a–1c,
lvin, Bull. U. S. Geol. Survey, IV, 1878, p. 728.—Whiteaves, Cont.
Pal., I, 1892, p. 285.
arcuata? Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 121.
arcuata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 289,
s. 1–3.
Iowa; Naples, New York; Eureka district, Nevada; Lake Win-
Canada.

ckei Hall. Lower Helderberg (Dev.).
eckii Hall, Pal. New York, III, 1859, p. 191, pl. 22, figs. 1a–1t.—
rican Jour. Sci., 2d ser., XL, 1865, p. 33.—Hall, Second Ann. Rep.
Geol., 1883, pl. 44, figs. 23, 24.
(Strophodonta) beckii Hall, Tenth Rep. N. Y. State Cab. Nat.
, p. 52, figs. 1–4.

Digitized by Google

Strophеodonta beckei Hall—Continued.

Strophеodonta (Leptostrophia) becki Hall and Clarke, Pal. New York, 1892, p. 288, pl. 13, figs. 23, 24.

Loc. Albany and Schoharie counties, New York; Kennedy Channel, Ar

Strophеodonta blainvillei (Billings). Lower

Strophomena blainvillei Billings, Pal. Fossils, II, 1874, p. 28, pl. 2, f fig. 1.

Strophеodonta (Leptostrophia) blainvillii Hall and Clarke, Pal. New Pt. I, 1892, p. 288.

Loc. Gaspé, Canada.

Obs. Compare with S. perplana.

Strophеodonta callawayensis Swallow. Hamilt

Strophodonta callawayensis, quadrata, and æquicostata Swallow, Louis Acad. Sci., I, 1860, p. 638.

Loc. Callaway County, Missouri.

Obs. See S. navalis.

Strophеodonta callosa Hall. Upper Helderbe

Strophodonta callosa Hall, Sixteenth Rep. N. Y. State Cab. Nat. p. 36;—Pal. New York, IV, 1867, p. 82, pl. 11, figs. 4–10; pl. 12, fi

Chonetes (Strophodonta?) callosa Hall, Second Ann. Rep. N. Y. S 1883, pl. 47, fig. 37.

Strophеodonta callosa Hall and Clarke, VIII, Pt. I, 1892, pl. 16, fig. 37.

Loc. Albany County, New York.

Strophеodonta calvini Miller. Chemu

Strophodonta quadrata Calvin (non Swallow, 1860), Bull. U. S. G Survey Terr., IV, 1878, p. 728.

Strophodonta calvini Miller, Cat. American Pal. Foss., 2d ed., Jan p. 298.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 122, p

Strophodonta exilis Calvin, American Jour. Sci., 3d ser., XXV, June,

Loc. Rockford and Independence, Iowa; Eureka district, Nevada.

Strophеodonta canace Hall and Whitfield. Chemu

Strophodonta canace Hall and Whitfield, Twenty-third Rep. N. Y. Nat. Hist., 1873, p. 236, pl. 11, figs. 8–11; abstract of same in 18 U. S. Geol. Expl. 40th Parl., IV, 1877, p. 246, pl. 3, figs. 1–3.

Loc. Rockford, Iowa; White Pine district, Nevada; Naples, New Yo

Strophеodonta cincta A. Winchell. Hamilt

Strophodonta cincta A. Winchell, Rep. Lower Peninsula Michigan, 18

Loc. Grand Traverse region, Michigan.

Obs. Insufficiently defined to be recognized.

Strophеodonta concava Hall. Corniferous and Hamilt

Strophomena (Strophodonta) concava Hall, Tenth Rep. N. Y. State Hist., 1857, pp. 115, 140, fig. 1.

Strophodonta concava Hall, Pal. New York, IV, 1867, p. 96, pl. 16, fig Second Ann. Rep. N. Y. State Geol., 1883, pl. 45, figs. 16–22.

Strophеodonta concava Hall and Clarke, Pal. New York, VIII, Pt. I, figs. 16–23.

Loc. New York, from Cayuga Lake westward to Lake Erie.

Strophеodonta corrugata (Conrad). Clin

Strophomena corrugata Conrad, Jour. Acad. Nat. Sci. Philadelphia, V 256, pl. 14, fig. 8.—Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 73, 72;—Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.—Foerste ton Soc. Nat. Hist., XXIV, 1890, p. 303, pl. 6, fig. 25.

Digitized by Google

rrugata (Conrad)—Continued.
gata Hall, Pal. New York, II, 1852, p. 59, pl. 21, figs. 2a–2c.
corrugata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 46,

corrugata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl.
Pt. II, 1895, pl. 84, fig. 14.
r, Wolcott, etc., New York; Cumberland Gap, Tennessee.

) corrugata pleuristriata (Foerste.) Clinton (Sil.).
gata (partim) Hall, Pal, New York, II, 1852, p. 59, pl. 21, figs. 2d, 2e.
corrugata var. pleuristriata Foerste, Proc. Boston Soc. Nat. Hist.,
0, p. 303, pl. 6, figs. 26, 27.
nd Gap, Tennessee.

) costata Owen. Hamilton (Dev.).
(?) costata Owen, Geol. Survey Wisconsin, Iowa, and Minnesota,
, pl. 3A, fig. 5; pl. 3, figs. 11, 11a.
t, Iowa.

ebristriata Hall. Upper Helderberg (Dev.).
crebristriata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII,
, pl. 14, fig. 3.
crebristriata Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist.,
;—Pal. New York, IV, 1867, p. 86, pl. 11, figs. 12, 13, 18–21.
nd Schoharie counties, New York.

missa (Conrad). Middle and Upper Devonian.
demissa Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p.
fig. 14.—Rogers, Geol. Pennsylvania, II, 1858, p. 827, fig. 666.—
Canadian Jour. Sci. Arts, 2d ser., VI, 1861, p. 341, figs. 116–118;—
da, 1863, p. 367, figs. 377a–d.
dimosa(?) Owen, Geol. Survey Wisconsin, Iowa, and Minnesota,
3A, fig. 14. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss.,

(Strophodonta) demissa Hall, Tenth Rep N. Y. State Cab. Nat.
, p. 137, fig. 1.—Meek, Trans. Chicago Acad. Sci., I, 1868, p. 87,

Strophodonta) subdemissa Hall, Tenth Rep. N. Y. State Cab. Nat.
p. 145.—Meek (non Hall), Trans. Chicago Acad. Sci., I, 1868, p. 88,
7.
demissa Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 495, pl. 3, fig. 5;—
ork, IV, 1867, p. 81, pl. 11, figs. 14–17; pl. 12, figs. 1–5.—Nicholson,
Ontario, 1873, p. 65.—White, Second Ann. Rep. Indiana Bureau of
nd Geol., 1880, p. 500, pl. 4, figs. 6, 7;—Tenth Rep. Indiana State
, p. 132, pl. 4, figs. 6, 7.—Whitfield, Geol. Wisconsin, IV, 1882, p.
fig. 18.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 45,
-Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 118, pl. 2, fig. 9.—
Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p.
figs. 10–16; pl. 33, fig. 22.—Whiteaves, Cont. Canadian Pal., I,
9.—Keyes, Geol. Survey Missouri, V, 1895, p. 70, pl. 39, fig. 7.
demissa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 14,

; Pennsylvania; Ohio; Indiana; Kentucky; Illinois; Iowa; Wis-
tario; Mackenzie and Athabasca rivers, Canada; Eureka district,

missa imitata Winchell. Hamilton (Dev.).
mitata A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 93.
verse region, Michigan.

Digitized by Google

Stropheodonta erratica A. Winchell. Hamilton (Dev.).

Strophodonta erratica and varieties solidicosta and fissicosta A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 93.

Loc. Grand Traverse region, Michigan.

Obs. This species may prove to be only a local variation of S. costata Owen.

Stropheodonta feildeni Etheridge. ? Lower Devonian.

Strophodonta feildeni Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 598, pl. 25, fig. 4.

Loc. Cape Hilgard, lat. 79° 41′.

Obs. Since this species is very closely related to S. magnifica of the Oriskany sandstone the horizon is probably Lower Devonian.

Stropheodonta galatea (Billings). Lower Devonian.

Strophomena galatea Billings, Pal. Fossils, II, 1874, p. 20, fig. 9.

Loc. Indian Cove, Gaspé, Canada.

Stropheodonta (?) **geniculata** (Shaler). Anticosti (Sil.).

Brachyprion geniculatum Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 63.

Loc. Near Southwest Point, Anticosti.

Stropheodonta (?) **gilpeni** (Dawson). Upper Arisaig (Sil.).

Strophomena gilpeni Dawson, Canadian Nat. Geol., n. ser., IX, 1880, p. 341.

Loc. Nova Scotia, Canada.

Stropheodonta hemispherica Hall. Upper Helderberg (Dev.)

Strophomena (Strophodonta) hemispherica Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 113.

Strophodonta hemispherica Hall, Pal. New York, IV, 1867, p. 90, pl. 13, figs. 12, 13;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 45, fig. 23.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 144, pl. 18, figs. 4–6.

Loc. New York; Ohio; Indiana; Kentucky; Ontario.

Stropheodonta inæquiradiata Hall. Upper Helderberg (Dev.).

Strophomena (Strophodonta) inæquiradiata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 113, figs. 1–3.

Strophomena inæquistriata Billings, Canadian Jour. Sci. Arts, VI, 1861, p. 338, fig. 113;—Geol. Canada, 1863, p. 367, fig. 375;—Pal. Fossils, II, 1874, p. 24, fig. 13; pl. 2, fig. 4; p. 240.

Strophodonta inæquiradiata Hall, Pal. New York, IV, 1867, p. 87, pl. 11, figs. 24–31; pl. 12, fig. 12; pl. 13, figs. 6–11;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 45, figs. 13, 14.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 120, pl. 11, fig. 11.

Stropheodonta inæquiradiata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 14, figs. 13, 14.

Loc. Albany and Schoharie counties, New York; Columbus, Ohio; Eureka district, Nevada; Gaspé Bay, Canada.

Stropheodonta inæquistriata (Conrad). Corniferous to Hamilton (Dev.).

Strophomena inæquistriata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 254, pl. 14, fig. 2.—Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 200, fig. 4.—Billings, Canadian Jour. Sci. Arts, VI, 1861, p. 338, figs. 113, 114;—Geol. Canada, 1863, p. 367, fig. 375.

Strophomena (Strophodonta) inæquistriata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 142.

Strophodonta inæquistriata Hall, Pal. New York, IV, 1867, p. 93, pl. 12, figs. 6–8; p. 106, pl. 18, fig. 2;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 45, figs. 1–6.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 145, pl. 17, figs. 10, 11.

Digitized by Google

equistriata (Conrad)—Continued.
(Douvillina) inæquistriata Hall and Clarke, Pal. New York, VIII, p. 289, pl. 14, figs. 1–6; pl. 15B, fig. 9.
Moscow, Darien, etc., New York; Ontario, Canada; Milwaukee, Wisconsin; Falls of Ohio.

enta (Conrad). Lower Helderberg (Dev.).
a Conrad, Second Ann. Rep. N. Y. Geol. Survey, 1838, pp. 112, 117.
denta Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 109, pl. 3,

denta Miller, American Pal. Fossils, 1877, p. 135.
erg Mountains," New York; Square Lake, Maine; Gaspé, Canada.

erstrialis (Phillips). Middle Devonian.
alis Phillips, Pal. Foss. Cornw. and W. Somerset, 1841, p. 61, pl.

nterstrialis Whiteaves, Cont. Canadian Pal., I, 1892, p. 286, pl.

ake Winnipegosis, Canada.

erstrialis (Vanuxem). Ithaca (Dev.).
terstrialis Vanuxem (non Phillips), Geol. N. Y.; Rep. Third Dist. , fig. 1.
ucronata Hall, Pal. New York, IV, 1867, p. 111, pl. 15, figs. 13, 14.
mira, Bath, etc., New York.
ion was directed to the above synonymy by Professor Williams l that of S. mucronata Conrad (non Hall).

vaensis Owen. ?Upper Devonian.
owensis Owen, Geol. Survey Wisconsin, Iowa, and Minnesota, .
k, near Rockford, Iowa.

ne (Billings). Upper Helderberg (Dev.).
ene Billings, Pal. Fossils, II, 1874, p. 27, pl. 2, fig. 5.
(Leptostrophia) irene Hall and Clarke, Pal. New York, VIII, Pt. I, .
ve, Gaspé Bay, Canada.

ia Hall. Hamilton (Dev.).
Strophodonta) textilis Hall (non 1852), Tenth Rep. N. Y. State Hist., 1857, p. 141, figs. 1–3.
extilis Hall, Pal. New York, IV, 1867, p. 108, pl. 18, figs. 3, 4.
unia Hall, Ibidem, 1867, corrigenda;—Second Ann. Rep. N. Y. gist, 1883, pl. 46, fig. 16.
(Leptostrophia) junia Hall and Clarke, Pal. New York, VIII, Pt. 88, pl. 15, fig. 16.
cow, Darien, etc., New York.

mperi Swallow. Hamilton (Dev.).
kemperi Swallow, Trans. St. Louis Acad. Sci., I, 1860, p. 636.
County, Missouri.

leda (Billings). Anticosti (Sil.).
eda Billings, Canadian Nat. and Geol., V, 1860, p. 55, figs. 2, 3;—s, I, 1862, p. 120, figs. 98, 99;—Geol. Canada, 1863, p. 311, fig. 316.
da Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 63.
leda Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 288.
da Whiteaves, Pal. Foss. III, Pt. III, 1897, p. 172.
t, Anticosti, Lake Winnepeg, Manitoba.

Digitized by Google

Strophеodonta lincklæni Hall. Oriskany (Dev.).

Strophodonta lincklæni Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 55;—Pal. New York, III, 1859, p. 415, pl. 93, figs. 2, 3.

Loc. Albany and Schoharie counties, New York.

Strophеodonta macra (Winchell and Marcy). Niagara (Sil.).

Strophomena macra W. and M., Mem. Boston Soc. Nat. Hist., I, 1865, p. 91.—Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 392.

Loc. Probably near Chicago, Illinois.

Strophеodonta macrostriata (Walcott). Lower Devonian.

Chonetes macrostriata Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 126, pl. 2, fig. 13; pl. 13, fig. 14.

Loc. Eureka district, Nevada.

Obs. The type material proves it to be a Strophеodonta.

Strophеodonta magnifica Hall. Oriskany (Dev.).

Strophodonta magnifica Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 54;—Pal. New York, III, 1859, pp. 414, 482, pl. 93, fig. 4; pl. 94, fig. 2; pl. 95, fig. 8; pl. 95A, figs. 15–19;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 44, figs. 27, 28.

Strophomena magnifica Billings, Canadian Jour. Sci. Arts, VI, 1861, p. 348;—Geol. Canada, 1863, p. 961, fig. 468.

Strophеodonta (Leptostrophia) magnifica Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 288, pl. 13, figs. 27, 28.

Loc. Albany and Schoharie counties, New York; Cumberland, Maryland; county of Haldimand, Ontario, Canada.

Strophеodonta magniventer Hall. Oriskany (Dev.).

Strophodonta magniventra Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 54;—Pal. New York, III, 1859, p. 411, pl. 92, figs. 2, 3; pl. 95, fig. 9;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 44, figs. 25, 26.

Strophomena magniventra Billings, Canadian Jour. Sci. Arts, VI, 1861, p. 349;—Geol. Canada, 1863, p. 961, fig. 469;—Pal. Fossils, II, 1874, p. 22, figs. 10–12, and pl. 2, fig. 2.

Strophеodonta (Leptostrophia) magniventra Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 288, pl. 13, figs. 25, 26.

Loc. Albany and Schoharie counties, New York; Cayuga, Ontario, and Gaspé Bay, Canada.

Strophеodonta mucronata (Conrad). Portage and Chemung (Dev.).

Strophomena mucronata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 257, pl. 14, fig. 10.

Strophomena interstrialis Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 266, fig. 5.

Strophodonta cayuta Hall, Pal. New York, IV, 1867, p. 110, pl. 19, figs. 1–5;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 46, figs. 18, 19.

Strophеodonta (Douvillina) cayuta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 289, pl. 15, figs. 18, 19; pl. 15B, figs. 7, 8; Pt. II, 1895, pl. 84, fig. 13.

Loc. Steuben County, New York.

Obs. See S. interstrialis.

Strophеodonta navalis Swallow. Hamilton (Dev.).

Strophodonta navalis, cymbiformis, subcymbiformis, and altidorsata Swallow, Trans. St. Louis Acad. Sci., I, 1860, pp. 635, 636, 637.

Strophodonta cymbiformis Keyes, Geol. Survey Missouri, V, 1895, p. 74.

Loc. Callaway County, Missouri.

Obs. The ten species of Strophеodonta described in this transaction by Swallow are all from one locality and appear to be nothing more than peculiar variations of S. demissa Conrad. No other locality is known where a species

Digitized by Google

Stropheodonta navalis Swallow—Continued.

of Brachiopoda has taken on as many variations as has S. demissa in the vicinity of Fulton, Missouri. Mr. D. K. Greger has furnished the writer over one hundred examples of this species and no two are exactly alike. Swallow's ten species are here reduced to three and one variety: S. navalis and var. boonensis, S. kemperi, and S. callawayensis.

Keyes (Geol. Survey Missouri, V, 1895) regards S. navalis, callawayensis, quadrata, and æquicostata as synonyms for S. demissa, while S. cymbiformis, subcymbiformis, kemperi, inflexa, and boonensis are regarded by him as but one species, S. cymbiformis. S. altidorsata is regarded as "insufficiently described."

Stropheodonta navalis boonensis Swallow. Hamilton (Dev.).

Strophodonta booensis and inflexa Swallow Trans. St. Louis Acad. Sci., I, 1860, pp. 637, 638.

Loc. Callaway County, Missouri.

Stropheodonta nearpassi Barrett. Coralline limestone (Sil.).

Leptæna——Hall, Pal. New York, II, 1852, pl. 74, fig. 3.

Strophodonta nearpassi Barrett, American Jour. Sci., 3d ser., XV, 1878, p. 372.

Loc. Near Port Jervis, New York.

Stropheodonta parva Owen. Hamilton (Dev.).

Strophodonta parva Owen, Geol. Survey Wisconsin, Iowa, and Minnesota, 1852, p. 584, pl. 3A, fig. 9.

Loc. New Buffalo, Iowa.

Obs. This may prove to be young S. demissa.

Stropheodonta parva Hall. Upper Helderberg (Dev.).

Strophodonta parva Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 37;—Pal. New York, IV, 1867, p. 85, pl. 11, figs. 5, 11.

Loc. Albany and Schoharie counties, New York.

Stropheodonta patersoni Hall. Oriskany to Corniferous (Dev.).

Strophomena (Strophodonta) patersoni Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 114, figs. 1–5.

Strophomena ? patersoni Billings, Canadian Jour. Sci. Arts, 2d ser., VI, 1861, p. 340, fig. 115.

Strophomena patersoni Billings, Geol. Canada, 1863, p. 367, fig. 374.—Nicholson, Pal. Prov. Ontario, 1873, p. 67.

Strophodonta patersoni Hall, Pal. New York, IV, 1867, p. 89, pl. 12, figs. 9–11; pl. 13, figs. 1–5;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 45, fig. 15.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 119.

Strophodonta patersoni Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 14, fig. 15.

Loc. Schoharie, Stafford, Williamsville, etc., New York; Columbus, Ohio; Bakeoven, Illinois; Eureka district, Nevada; county of Haldimand, Ontario, Canada.

Strophodonta perplana (Conrad). Upper Helderberg-Chemung (Dev.).

Strophomena perplana Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 257, pl. 14, fig. 11.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 827, fig. 665.—Billings, Canadian Jour. Sci. Arts, 2d ser., VI, 1861, p. 343;—Proc. Portland Soc. Nat. Hist., 1863, p. 109.—Nicholson, Pal. Prov. Ontario, 1873, p. 64.

Strophomena delthyris Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842 p. 258, pl. 14, fig. 19.

Strophomena pluristriata Conrad, Ibidem, 1842, p. 259.

Strophomena crenistria Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 171, fig. 4.

Digitized by Google

Strophеodonta perplana (Conrad)—Continued.

Strophomena (Strophodonta) crenistria Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 111.

Strophomena (Strophodonta) fragilis Hall, Ibidem, 1857, p. 143.

Strophodonta fragilis Hall, Geol. Iowa, I, Pt. II, 1858, p. 496, pl. 3, fig. 6.

Strophodonta perplana Hall, Pal. New York, IV, 1867, pp. 92, 98, pl. 11, fig. 22; pl. 12, figs. 13–15; pl. 17, fig. 1.—Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 25.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 46, figs. 2–15.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 120, pl. 13, fig. 11.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 147, pl. 18, fig. 17.—Beecher, American Jour. Sci., 3d ser., XLI, 1891, p. 357, pl. 17, fig. 17.—Whiteaves, Cont. Canadian Pal., I, 1891, p. 220.

Strophеodonta (Leptostrophia) perplana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 288, pl. 15, figs. 2–13.

Loc. New York; Pennsylvania; Maryland; Ohio; Indiana; Kentucky; Illinois; Iowa; Wisconsin; Eureka district, Nevada; Square Lake, Maine; Ontario and Peace River, Canada; Rio Maecuru and Rio Curua, Province of Para, Brazil.

Strophеodonta perplana nervosa Hall. Portage and Chemung (Dev.).

Strophomena nervosa Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 266, fig. 1.

Strophodonta perplana var. nervosa Hall, Pal. New York, IV, 1867, p. 113, pl. 19, figs. 13–16;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 46, fig. 17.

Strophеodonta perplana var. nervosa Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, figs. 14, 15, 17.

Loc. Ithaca, Bath, Campbelltown, etc., New York.

Strophеodonta perplana tulliensis Williams. Tully (Dev.).

Strophodonta perplana var. tulliensis Williams, Bull. Geol. Soc. America, I, 1890, p. 493, pl. 12, figs. 1–4.

Loc. Cuyler, New York.

Strophеodonta planulata Hall. Lower Helderberg (Dev.).

Strophodonta planulata Hall, Pal. New York, III, 1859, p. 184, pl. 16, figs. 9–12.

Loc. Schoharie, Dryhill, and Litchfield, New York.

Strophеodonta plicata Hall. Hamilton (Dev.).

Strophodonta plicata Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 90;—Pal. New York, IV, 1867, p. 114.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 149.

Loc. Iowa City and Independence, Iowa; Thedford, Ontario; Falls of Ohio.

Strophеodonta prisca Hall. Clinton (Sil.).

Strophеodonta prisca Hall, Pal. New York, II, 1852, p. 63, pl. 21, fig. 9.

Loc. Kirkland, Oneida County, New York.

Strophеodonta profunda Hall. Clinton and Niagara (Sil.).

Leptæna profunda Hall, Pal. New York, II, 1852, p. 61, pl. 21, figs. 4, 5.

Strophomena profunda Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.

Strophomena niagarensis Winchell and Marcy, Mem. Boston Soc. Nat. Hist., I, 1865, p. 92, pl. 2, fig. 9.

Strophodonta profunda Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, pp. 369, 392, pl. 13, figs. 3, 4;—Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 151, pl. 23, figs. 9, 10;—Eleventh Rep. Indiana State Geol., 1882, p. 289, pl. 23, figs. 9, 10; pl. 27, fig. 18;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 44, figs. 1–5 (? figs. 19, 20).—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 148, pl. 29, fig. 26; pl. 17, figs. 20, 21.

Digitized by Google

profunda Hall—Continued.
nta (Brachyprion) profunda Hall and Clarke, Pal. New York, VIII, 892, pl. 13, figs. 1–5 (? 19, 20); pl. 20, figs. 29–31; Pt. II, 1895, pl. 84,

port, New York; Waldron, Indiana; Bridgeport, Illinois; Racine, sin; Louisville, Kentucky.

textilis Hall. Coralline (Sil.).
nta textilis Hall, Pal. New York, II, 1852, p. 327, pl. 74, fig. 6.
nta (Leptostrophia) textilis Hall and Clarke, Pal. New York, VIII, 892, p. 288.
arie, New York.

tullia (Billings). Upper Helderberg (Dev.).
na tullia Billings, Pal. Fossils, II, 1874, p. 29, pl. 2, fig. 6.
nta (Leptostrophia) tullia Hall and Clarke, Pal. New York, VIII, Pt. p. 288.
Joli and Split Rock, Percé, Canada.

variabilis Calvin. Chemung (Dev.).
ta variabilis Calvin, Bull. U. S. Geol. Geogr. Survey Terr., IV, 1878,

nta variabilis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 15B, figs. 4–6.
endence, Iowa; Naples, New York.

varistriata (Conrad). Lower Helderberg (Dev.).
na varistriata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, pl. 14, fig. 6.—Billings, Pal. Fossils, II, 1874, p. 26, pl. 2, fig. 3.
na rectilateris Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1812, pl. 14, fig. 7.
na impressa Conrad, Ibidem, 1842, p. 255.
ta varistriata Hall, Pal. New York, III, 1859, p. 180, pl. 8, figs. 1–16; figs. 1–8;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 44, figs. 6–16 21, 22).
nta (Brachyprion) varistriata Hall and Clarke, Pal. New York, VIII, 892, pl. 13, figs. 6–16, 21, 22.
y and Schoharie counties, New York; Dalhousie, New Brunswick, spé, Canada.

varistriata arata Hall. Lower Helderberg (Dev.).
ta varistriata var. arata Hall, Pal. New York, III, 1859, p. 183, pl. 18, —Second Ann. Rep. N. Y. State Geol., 1883, pl. 44, figs. 17, 18.
nta varistriata var. arata Hall and Clarke, Pal. New York, VIII, Pt. pl. 13, figs. 17, 18.
on and Albany counties, New York; Arisaig, Nova Scotia (Ami).

vascularia Hall. Oriskany (Dev.).
ta vascularia Hall, Pal. New York, III, 1859, p. 412, pl. 92, fig. 4; fig. 10 (? pl. 93, fig. 2).
y County, New York.

(?) **ventricosa** (Shaler). Anticosti (Sil.).
on ventricosa Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 63.
west Point, Anticosti.

a æquicostata Swallow=S. callawayensis.
a altidorsata Swallow=S. navalis.
a ampla Hall=Strophonella ampla.

Digitized by Google

Strophodonta boonensis Swallow=S. navalis boonensis.
Strophodonta cælata Hall=Strophonella cælata.
Strophodonta cavumbona Hall=Strophonella cavumbona.
Strophodonta cayuta Hall=Stopheodonta mucronata.
Strophodonta cymbiformis Swallow=S. navalis.
Strophodonta exilis Calvin=Stropheodonta calvini.
Strophodonta fragilis Hall=S. perplana.
Strophodonta geniculata Hall=Strophonella geniculata.
Strophodonta headleyana Hall=Strophonella headleyana.
Strophodonta hybrida Hall and Whitfield=Strophonella reversa.
Strophodonta imitata A. Winchell=S. demissa imitata.
Strophodonta inflexa Swallow=S. navalis boonensis.
Strophodonta intermedia Hall=Hipparionyx proximus.
Strophodonta leavenworthana Hall=Strophonella leavenworthana.
Strophodonta mucronata Hall=S. interstrialis.
Strophodonta nacrea Hall=Pholidostrophia iowaensis.
Strophodonta punctulifera Hall=Strophonella punctulifera.
Strophodonta quadrata Swallow=S. callawayensis.
Strophodonta quadrata Calvin (non Swallow)=S. calvini.
Strophodonta reversa Hall=Strophonella reversa.
Strophodonta striata Hall=Strophonella striata.
Strophodonta subcymbiformis Swallow=S. navalis.
Strophodonta subdemissa Hall=S. demissa.
Strophodonta textilis Hall, 1857 (not 1852)=S. junia.

STROPHOMENA (Rafinesque) Blainville. Genotype S. rugosa Blainv.

Strophomena Blainville, Manuel de Malacologie et Conchyliologie, I, 1825, p. 513, pl. 53, fig. 2.—Defrance, Dictionnaire des Sciences Naturelles, LI, 1827, p. 151 and atlas.—King, Mon. Permian Fossils, Pal. Soc., 1850, p. 103.—Meek (partim), Pal. Ohio, I. 1873, p. 73.—Œhlert, Fischer's Manuel de Conchyliologie, 1887, p. 1281.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 245.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 384.—Hall and Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 283.

Strophomenes Rafinesque, Desc. Remarkable Objects in the Cabinet of Professor Rafinesque, 1831, p. 4.

Hemipronites Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl. XIV, 172, 1864, p. 24.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 41.

Obs. This genus is characteristic of the Ordovician, and probably does not extend into the Silurian, where Orthothetes replaces Strophomena. A number of Silurian species are still left under Strophomena since their generic characters are unknown.

Strophomena acanthoptera Whiteaves=Stropheodonta acanthoptera.
Strophomena acutiradiata Hall=Chonetes acutiradiatus.
Strophomena alternata Emmons=Rafinesquina alternata.
Strophomena alternata fracta Meek=Rafinesquina alternata fracta.
Strophomena alternata loxorhytis Meek=Rafinesquina alternata loxorhytis.
Strophomena alternistriata Hall=Rafinesquina alternata alternistriata.

Digitized by Google

Strophomena (?) alterniradiata Shaler. Anticosti (Sil.).
Strophomena alterniradiata Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 63.
Loc. Southwest Point, Anticosti.

Strophomena ampla Hall=Strophonella ampla.

Strophomena anologa Davidson, 1863=Leptæna rhomboidalis.

Strophomena angulata Owen=Rafinesquina alternata.

Strophomena anticostiensis Shaler=Rafinesquina alternata.

Strophomena (?) antiquata Sowerby. Anticosti (Sil.).
Strophomena antiquata Sowerby, Murchison's Silurian System, 1839.—Billings, Pal. Fossils, I, 1862, p. 129, fig. 107.
Loc. Europe; Anticosti; forks of the Chatts River, Gaspé.
Obs. This identification is doubtful.

Strophomena approximata (James). Lorraine (Ord.).
Streptorhynchus approximata James, The Paleontologist, 5, 1881, p. 43; 2, 1878, p. 15.
Loc. Dearborn County, Indiana.
Obs. Not defined so as to be recognizable.

Strophomena arctostriata Hall=Orthothetes chemungensis arctostriatus.

Strophomena (?) arcuata Shaler. Anticosti (Sil.).
Strophomena arcuata Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 62.
Loc. Ellis Bay, Anticosti.

Strophomena (?) arethusa Billings. Lorraine (Ord.).
Strophomena arethusa Billings, Pal. Fossils, I, 1862, p. 132.
Loc. Observation Cape, Anticosti.

Strophomena atava Matthew=Rafinesquina atava.

Strophomena aurora Billings=Rafinesquina aurora.

Strophomena bifurcata Hall=Orthothetes chemungensis.

Strophomena billingsi Winchell and Schuchert. Trenton (Ord.).
Strophomena recta Billings (non Conrad), Pal. Fossils, I, 1862, p. 130, fig. 108.
Strophomena billingsi W. and S., Minnesota Geol. Survey, III, 1893, p. 397, fig. 32.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 170.
Loc. Ottawa, Canada; St. Paul, Cannon Falls, and Fountain, Minnesota; East Selkirk, Manitoba.

Strophomena (?) bipartita Hall. Coralline (Sil.).
Leptæna bipartita Hall, Pal. New York, II, 1852, p. 326, pl. 74, figs. 4, 5.
Strophomena bipartita Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.
Loc. Schoharie, New York.

Strophomena blainvillii Billings=Stropheodonta blainvillei.

Strophomena camerata Conrad=Rafinesquina deltoidea.

Strophomena cardinalis (Whitfield). Lorraine (Ord.).
Streptorhynchus cardinale Whitfield, Geol. Wisconsin, IV, 1882, p. 261, pl. 12, figs. 9, 10.
Strophomena cardinale Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 252.
Loc. Delafield, Wisconsin.

Strophomena carinata Conrad, 1838=Tropidoleptus carinatus.

Strophomena carinata Conrad, 1842 (non 1838)=Chonetes coronatus.

Strophomena ceres Billings=Rafinesquina ceres.

Digitized by Google

Strophomena chemungensis Conrad=Orthothetes chemungensis.

Strophomena concava Hall=Stropheodonta concava.

Strophomena conradi Hall (1859)=Strophonella conradi.

Strophomena conradi Hall and Clarke. Trenton (Ord.).

Strophomena conradi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 344, pl. 9A, fig. 3; pl. 20, figs. 32, 33.

Loc. Jacksonburg, New York.

Strophomena convexa Owen=S. incurvata.

Strophomena cornuta Hall=Chonetes cornutus.

Strophomena corrugata Conrad=Stropheodonta corrugata.

Strophomena crebristriata Conrad=Stropheodonta crebristriata.

Strophomena crenistria Hall=Stropheodonta perplana.

Strophomena (?) declivis James. Lorraine (Ord.).

Strophomena declivis James, Cincinnati Quart. Jour. Sci., I, 1874, p. 240.

Loc. Boyds Station, Kentucky.

Strophomena deflecta Conrad=Dinorthis deflecta.

Strophomena delthyris Conrad=Stropheodonta perplana.

Strophomena deltoidea Conrad=Rafinesquina deltoidea and R. minnesotaensis.

Strophomena demissa Conrad=Stropheodonta demissa.

Strophomena depressa Vanuxem=Leptæna rhomboidalis.

Strophomena depressa ventricosa Hall=Leptæna rhomboidalis ventricosa.

Strophomena (?) doneti Salter. Silurian.

Strophomena doneti Salter, Jour. of a Voyage in Baffins Bay and Barrow Straits, 1852.

Loc. Wellington Channel.

Strophomena elegantula Hall=Plectambonites transversalis.

Strophomena (?) elliptica Conrad. Niagara (Sil.).

Strophomena elliptica Conrad, Third Ann. Rep. Geol. Survey New York, 1839, p. 64.

Loc. Rochester, New York.

Strophomena (?) elongata Conrad. Lower Helderberg (Dev.).

Strophomena elongata Conrad, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 259.

Loc. Schoharie, New York.

Strophomena emaciata Winchell and Schuchert. Trenton (Ord.).

Strophomena emaciata W. and S., American Geol., IX, 1892, p. 287;—Minnesota Geol. Survey, III, 1893, p. 399, pl. 31, figs. 22–24.

Loc. Near Cannon Falls, Minnesota.

Strophomena euglyphya Conrad, and Roemer=Strophonella punctulifera.

Strophomena fasciata Hall=Rafinesquina fasciata.

Strophomena filitexta Meek, White, and Hall=S. neglecta or S. incurvata.

Strophomenes flexilis Rafinesque. "Limestone of Ohio."

Same paper as for S. levigata, 1831, p. 4.

Obs. Not defined so as to be recognizable.

Digitized by Google

Strophomena fluctuosa Billings. Lorraine (Ord.).

Strophomena fluctuosa Billings, Canadian Nat. Geol., V, 1860, p. 57, fig. 6;—Pal. Fossils, I, 1862, p. 123, fig. 102;—Geol. Canada, 1863, p. 209, fig. 207.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251, pl. 11A, figs. 4, 5.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 395, pl. 31, figs. 14–17.

Loc. Charletor Point, Anticosti; Spring Valley, etc., Minnesota.

Strophomena fontinalis White=Dinorthis fontinalis.

Strophomena fragilis Hall=Stropheodonta perplana.

Strophomena galatea Billings=Stropheodonta galatea.

Strophomena gibbosa James=Leptæna rhomboidalis.

Strophomena (?) gibbosa Conrad. Upper Helderberg (Dev.).

Strophomena gibbosa Conrad, Fifth Ann. Rep. Geol. Survey New York, 1841, p. 54.

Loc. Helderberg Mountains, New York.

Strophomena gilpeni Dawson=Stropheodonta gilpeni.

Strophomena halli Sardeson=Leptæna charlottæ.

Strophomena hallie Miller. Utica (Ord.).

Streptorhynchus (?) hallie Miller, Cincinnati Quart. Jour. Sci., I, 1874, p. 148, figs. 14–16.

Streptorhynchus hallanum Miller, North American Geol. and Pal., 1889, p. 378.

Strophomena hallie Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 252.

Loc. Cincinnati, Ohio.

Strophomena hanoverensis Foerste=Strophonella striata.

Strophomena hecuba Billings. Lorraine (Ord.).

Strophomena hecuba Billings, Canadian Nat. Geol., V, 1860, p. 60, fig. 7;—Pal. Fossils, I, 1862, p. 126, fig. 104;—Geol. Canada, 1863, p. 209, fig. 206.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 252.

Loc. Anticosti.

Strophomena hemispherica Hall=Stropheodonta hemispherica.

Strophomena (?) imbecilis Billings. ?Calciferous (Ord.).

Strophomena imbecilis Billings, Pal. Fossils, I, 1865, p. 219.

Loc. Near Portland Creek, Newfoundland.

Strophomena imbrex Billings=Rafinesquina imbrex.

Strophomena impressa Conrad=Stropheodonta varistriata.

Strophomena inæquiradiata Hall=Stropheodonta inæquiradiata.

Strophomena incrassata=Rafinesquina incrassata and R. minnesotaensis.

Strophomena incurvata (Shepard). Trenton (Ord.).

Producta incurvata Shepard, American Jour. Sci., XXXIV, 1838, p. 144, figs. 1, 2.

Orthis incurvata Castelnau, Essai sur le Système Silurien de l'Amérique Septentrionale, 1843, p. 38.

Strophomena convexa Owen, Geol. Expl. Iowa, Wisconsin, and Illinois, 1844, p. 70, pl. XVII, fig. 2.

Leptæna filitexta Hall, Pal. New York, I, 1847, p. 111, pl. 31B, fig. 3.

Strophomena filitexta Billings, Canadian Nat. Geol., I, 1856, p. 203, figs. 1, 2.—Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 70.—Billings, Geol. Canada, 1863, p. 164, fig. 142.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251, pl. 9, figs. 1–7; pl. 9A, figs. 11–14 (non figs. 10, 15=S. neglecta).

Streptorhynchus filitexta Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 39, figs. 1–7; pl. 42, figs. 11–14 (non figs. 10, 15=S. neglecta).

Digitized by Google

Strophomena incurvata (Shepard)—Continued.

Strophomena incurvata Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 385, pl. 30, figs. 36–40.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 167.

Loc. New York; Kentucky; Tennessee; Missouri; Wisconsin; Iowa; Minnesota; Manitoba; Canada.

Strophomena inquassa Sardeson = Rafinesquina minnesotaensis inquassa.

Strophomena interstrialis Hall = Stropheodonta mucronata.

Strophomena interstrialis Vanuxem, and Hall = Stropheodonta interstrialis.

Strophomena irene Billings = Stropheodonta irene.

Strophomena ithacensis Vanuxem = Atrypa reticularis.

Strophomena (?) julia Billings. Anticosti (Sil.).

Strophomena julia Billings, Pal. Fossils, I, 1862, p. 127, fig. 105.

Leptæna julia Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 65.

Loc. Anticosti.

Strophomena kingi Whitfield = Rafinesquina kingi.

Strophomena lævis Emmons. Birdseye (Ord.).

Strophomena lævis Emmons, Geol. New York; Rep. Second Dist., 1842, p. 385, fig. 972.

Loc. Great Bend, Jefferson County, New York.

Strophomena lachrymosa Conrad = Productella lachrymosa.

Strophomena leda Billings = Stropheodonta leda.

Strophomena lepida Hall = Pholidostrophia iowaensis.

Strophomenes levigata Rafinesque. "Kentucky limestone."

Enumeration and Account of Some Remarkable Natural Objects in the Cabinet of Professor Rafinesque, 1831, p. 4.

Obs. Not defined so as to be recognizable.

Strophomena lima Conrad = Productella lachrymosa lima.

Strophomena lineata Conrad = Chonetes lineatus.

Strophomena macra Winchell and Marcy = Stropheodonta macra.

Strophomena magnifica Billings = Stropheodonta magnifica.

Strophomena magniventra Billings = Stropheodonta magniventer.

Strophomena membranacea Vanuxem = Productella hirsuta.

Strophomena minnesotensis Winchell = Rafinesquina minnesotaensis.

Strophomena (?) minor (Walcott). Pogonip (Ord.).

Streptorhynchus minor Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 75, pl. 11, fig. 9.

Loc. Eureka district, Nevada.

Strophomena (?) modesta Conrad. ? Clinton (Sil.).

Strophomena modesta Conrad, Third Ann. Rep. N. Y. Geol. Survey, 1839, p. 64.

Loc. Rochester, New York.

Obs. Compare with Plectambonites sericea and P. elegantula.

Strophomena mucronata Hall (non Conrad) = Chonetes mucronatus.

Strophomena mucronata Conrad (non Hall) = Stropheodonta mucronata.

Strophomena nacrea Hall = Pholidostrophia iowaensis.

Strophomena (?) nassula Conrad. Carboniferous.

Strophomena nassula Conrad, Proc. Acad. Nat. Sci. Philadelphia, III, 1846, p. 23.

Loc. Jersey Shore, Lycoming County, Pennsylvania.

Digitized by Google

Strophomena nasuta Conrad=Rafinesquina alternata nasuta.

Strophomena neglecta (James). Lorraine (Ord.).

Strophomena filitexta Meek (non Hall), Pal. Ohio, I, 1873, p. 83, pl. 6, fig. 5.

? Strophomena filitexta White, U. S. Geol. and Geogr. Survey west 100th Merid., IV, 1875, p. 69, pl. 4, fig. 8.

Hemipronites filitextus Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 43.

Streptorhynchus neglecta James, The Paleontologist, 5, 1881, p. 41.

Streptorhynchus filitextus (partim) Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 42, figs. 10, 15 (non figs. 11–14); pl. 39, figs. 1–7.

Strophomena filitexta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 9A, figs. 10, 15 (non figs. 11–14); pl. 11A, fig. 3.

Strophomena neglecta Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 388.

Loc. Oxford, Clarksville, Waynesville, etc., Ohio; Richmond, Versailles, etc., Indiana; Savanna, Illinois; ? Silver City, New Mexico.

Strophomena neglecta acuta Winchell and Schuchert. Lorraine (Ord.).

Strophomena neglecta var. acuta W. and S., Minnesota Geol. Survey, III, 1893, p. 388, pl. 31, figs. 6, 7.

Loc. Spring Valley, Minnesota.

Strophomena ? nemea Hall and Whitfield=Dalmanella pogonipensis.

Strophomena nervosa Hall=Stropheodonta perplana nervosa.

Strophomena niagarensis Winchell and Marcy=Stropheodonta profunda.

Strophomena nitens Billings=Rafinesquina nitens.

Strophomena nutans Meek. Lorraine (Ord.).

Strophomena (Hemipronites) nutans (James) Meek, Pal. Ohio, I, 1873, p. 77, pl. 6, fig. 1.

Hemipronites nutans Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 46.

Streptorhynchus nutans Miller, N. American Geol. Pal., 1889, p. 378.

Strophomena nutans Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251, pl. 8, fig. 11; pl. 9A, figs. 5–7; pl. 11A, figs. 6, 7.

Loc. Oxford, Clarksville, etc., Ohio; Richmond, Versailles, etc., Indiana.

Strophomena obscura Hall=Rafinesquina obscura.

Strophomena (?) orthididea Hall. Clinton (Sil.).

Leptæna orthididea Hall, Pal. New York, II, 1852, p. 62, pl. 21, fig. 7.

Strophomena orthididea Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.

Loc. Kirkland, Oneida County, New York.

Strophomena patenta Hall=Strophonella patenta.

Strophomena patersoni Hall=Stropheodonta patersoni.

Strophomena pecten Roemer, and Billings=Orthothetes subplanus.

Strophomena pectinacea Hall=Orthothetes chemungensis.

Strophomena perplana Conrad=Stropheodonta perplana.

Strophomena philomela Billings. Anticosti (Sil.).

Strophomena philomela Billings, Canadian Nat. Geol., V, 1860, p. 56, figs. 4, 5;—Pal. Fossils, I, 1862, p. 122, figs. 100, 101;—Geol. Canada, 1863, p. 311, fig. 317.

Loc. Anticosti.

Strophomena planiconvexa Hall. Lorraine (Ord.).

Leptæna planoconvexa Hall, Pal. New York, I, 1847, p. 114, pl. 31B, fig. 7.

Digitized by Google

Strophomena planiconvexa Hall—Continued.

Strophomena planoconvexa Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 70.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251, pl. 9, figs. 19, 20.

Strophomena (Hemipronites) planoconvexa Meek, Pal. Ohio, I, 1873, p. 82, pl. 6, fig. 2.

Hemipronites planoconvexa Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 48.

Streptorhynchus planoconvexus Miller, American Pal. Fossils, 1877, p. 134.—Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 39, figs. 19, 20.

Loc. Cincinnati, Ohio.

Strophomena planidorsata Winchell and Schuchert. Lorraine (Ord.).

Strophomena planodorsata W. and S., American Geol., IX, 1892, p. 286;—Minnesota Geol. Survey, III, 1893, p. 393, pl. 31, figs. 8–10.

Loc. Spring Valley, Minnesota; Iron Ridge, Wisconsin; Wilmington, Illinois.

Strophomena planumbona Hall=S. rugosa.

Strophomena plicata Meek=S. rugosa subtenta.

Strophomena plicifera Hall=Dalmanella plicifera.

Strophomena pleuristriata Conrad=Stropheodonta perplana.

Strophomena profunda Hall=Stropheodonta profunda.

Strophomena punctulifera Vanuxem=Strophonella punctulifera.

Strophomena pustulosa Hall (non Phillips)=Strophalosia truncata.

Strophomena radiata Vanuxem=Strophonella radiata.

Strophomena recta Conrad=Dinorthis deflecta.

Strophomena recta Billings=S. billingsi.

Strophomena rectilateraria Meek and Worthen=Strophonella cavumbona.

Strophomena rectilateris Conrad=Stropheodonta varistriata.

Strophomena (?) reticulata Shaler. Niagara (Sil.).

Strophomena reticulata Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 62.

Loc. Anticosti.

Strophomena rhomboidalis=Leptæna rhomboidalis.

Strophomena rugosa Hall (non Blainville)=Leptæna rhomboidalis.

Strophomena rugosa (Rafinesque MS.) Blainville. Lorraine (Ord.).

Strophomena rugosa (Rafinesque) Blainville, Malacologie et Conchyliologie, I, 1825, p. 513, pl. 53, figs. 2, 2a.—King, Mon. Permian Fossils, Pal. Soc., 1850, p. 103.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 247, figs. 13, 14.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 390, pl. 31, figs. 4, 5.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 168.

Strophomenes rugosa Defrance, Dictionaire des Sciences Naturelles, I, 1827, p. 151 and atlas.

Leptæna planumbona Hall, Pal. New York, I, 1847, p. 112, pl. 31, fig. 4.

Leptæna (n. sp.?) Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, pl. 2B, fig. 21. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17876.]

Strophomena planumbona Hall, Geol. Wisconsin, I, 1862, p. 54, fig. 7.—White, Second Ann. Rep. Indiana Bureau Statistics and Geol., 1880, p. 483, pl. 2, figs. 13, 14;—Tenth Rep. Indiana State Geol., 1881, p. 115, pl. 2, figs. 13, 14.—Shaler (partim), Mem. Kentucky Geol. Survey, 1887, p. 13, pls. 4, 5.—Keyes, Geol. Survey Missouri, V, 1895, p. 73.

Strophomena (Hemipronites) planumbona Meek, Pal. Ohio, I, 1873, p. 79, pl. 6, fig. 3.

Digitized by Google

osa (Rafinesque MS.) Blainville—Continued.
us (Strophomena) elongata James, Cincinnati Quart. Jour. Sci., 240.
planumbona Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 45.
us planumbonus Miller, American Pal. Fossils, 1877, p. 134.
us elongata Mickelborough and Wetherby, Jour. Cincinnati Soc. , I, 1878, p. 76.
us planumbona Hall, Second Ann. Rep. N. Y. State Geol., 1883, . 15–17; pl. 42, figs. 8, 9.
planumbona or rugosa Hall and Clarke, Pal. New York, VIII, Pt. 251, pl. 9, figs. 15–17; pl. 9A, figs. 8, 9.
liana; Kentucky; Missouri; Minnesota and Anticosti. Lower Fort nitoba. Probably also at Lattners, Iowa, and Ironridge, Wisconsin.

osa subtenta (Hall). Lorraine (Ord.).
subtenta Conrad, Fifth Ann. Rep. N. Y. Geol. Survey, 1841, p. 37 1).—Billings, Pal. Fossils, I, 1862, p. 132, fig. 109 on p. 130.
enta Hall, Pal. New York, I, 1847, p. 115, pl. 31B, fig. 9.
(Hemipronites) plicata (James) Meek, Pal. Ohio, I, 1873, p. 81, pl.

subtenta Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 46.
rugosa var. subtenta Winchell and Schuchert, Minnesota Geol. I, 1893, p. 393.—Whiteaves, Pal. Foss., III, Pt. III, 1897, p. 169.
as for S. rugosa.

ugosa ventricosa H.=Leptæna rhomboidalis ventricosa.

fieldi Winchell and Schuchert. Trenton (Ord.).
scofieldi W. and S., American Geol., IX, April, 1892, p. 286;— Geol. Survey, III, 1893, p. 398, pl. 31, figs. 18–21.
us subsulcatum Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 92, p. 335, pl. 4, fig. 39.
Falls, Minneapolis, and St. Paul, Minnesota; Beloit, Wisconsin.

emifasciata Hall=Strophonella semifasciata.

emiovalis Conrad (non Shaler)=Plectambonites sericeus.

semiovalis Shaler. Anticosti (Sil.).
semiovalis Shaler, Bull. Mus. Comp. Zool., 4, 1865, p. 61.

tata Winchell and Schuchert. Trenton (Ord.).
septata W. and S., American Geol., IX, 1892, p. 285;—Minnesota ey, III, 1893, p. 390, pl. 30, figs. 1–3.
Minneapolis, and Rochester, Minnesota.

ericea=Plectambonites sericeus.

etigera Hall=Chonetes setigerus.

siluriana Davidson. Silurian.
siluriana Davidson, British Sil. Brach., Pal. Soc., 1871, p. 303, pl. 47, -Etheridge, Quart. Jour. Geol. Soc. London, XXXIV, 1878, p. 597. ; Cape Leidy, lat. 79° 38′.

inuata Emmons (non Meek)=S. sulcata.

uata Meek. Lorraine (Ord.).
(Hemipronites) sinuata (James) Meek, Pal. Ohio, I, 1873, p. 87, pl. on S. sinuata Emmons, 1855).
sinuata Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 50.
sinuata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251.
ti, Ohio.

Digitized by Google

Strophomena squamula James=Rafinesquina squamula.

Strophomena striata Hall=Strophonella striata.

Strophomena subplana Conrad=Orthothetes subplanus.

Strophomena subtenta Conrad=S. rugosa subtenta.

Strophomena sulcata (Verneuil). Lorraine (Ord.).

Leptæna sulcata Verneuil, Bull. Geol. Soc. France, 2d ser., V, 1848, p. 350.

Strophomena sinuata Emmons, American Geol., I, 1855, p. 199, fig. 61.

Strophomena (Hemipronites?) sulcata Meek, Pal. Ohio, I, 1873, p. 85, pl. 5, fig. 4.

Hemipronites sulcata Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 48, fig. 5.

Streptorhynchus sulcatus Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 39, figs. 8, 9.

Strophomena sulcata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 9, figs. 8, 9; pl. 11A, fig. 8.

Loc. Oxford, Clarksville, etc., Ohio; Richmond, Indiana.

Strophomena syrtalis Conrad=Chonetes coronatus.

Strophomena (?) talacastrensis Kayser. Ordovician.

Strophomena talacastrensis Kayser, Palæontographica, Suppl., III, 1876, p. 20, pl. 3, fig. 20.

Loc. Talacastra, Cordillere San Juan, Argentine Republic.

Strophomena tenuilineata Conrad=Rafinesquina tenuilineata.

Strophomena tenuistriata=Leptæna rhomboidalis.

Strophomena textilis Hall=Stropheodonta junia.

Strophomena thalia Billings. Trenton (Ord.).

Strophomena thalia Billings, Canadian Nat. Geol., V, 1860, p. 59;—Pal. Fossils, I, 1862, p. 125, fig. 103;—Geol. Canada, 1863, p. 164, fig. 143.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251.

Loc. Ottawa, Canada.

Strophomena transversalis Hall=Plectambonites transversalis.

Strophomena trentonensis Winchell and Schuchert. Trenton (Ord.).

Leptæna subtenta (partim) Hall, Pal. New York, I, 1847, p. 115.

Streptorhynchus subtenta Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 39, fig. 18.

Strophomena subtenta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251, pl. 9, fig. 18.

Strophomena trentonensis W. and S., Minnesota Geol. Survey, III, 1893, p. 389, pl. 30, fig. 41.

Loc. Cannon Falls, Minneapolis, and Fountain, Minnesota; Janesville and Beloit, Wisconsin; Frankfort, Kentucky; Nashville, Tennessee; Trenton Falls, New York.

Strophomena trilobata (Owen). Trenton (Ord.).

Leptæna trilobata Owen, Geol. Survey Wisconsin, Iowa, Minnesota, 1852, p. 584, pl. 2, figs. 17, 18. [See specimens in U. S. Nat. Mus., Cat. Invert. Foss., 17875.]

Strophomena trilobata Miller, American Pal. Fossils, 1877, p. 138.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 395, pl. 31, figs. 12, 13.—Whiteaves, Pal. Foss., III, Pt. III, 1897, pp. 169, 241.

Loc. Turkey River, Iowa; Goodhue County, Minnesota; Lake Winnipeg, Manitoba.

Strophomena tullia Billings=Stropheodonta tullia.

Strophomena ulrichi James=Rafinesquina ulrichi.

Strophomena unicostata Meek and Worthen=Rafinesquina unicostata.

Digitized by Google

Strophomena undulatus Vanuxem=Leptæna rhomboidalis.

Strophomena undulosa Conrad=Leptæna undulosa.

Strophomena varistriata Conrad=Stropheodonta varistriata.

Strophomena vetusta James. Lorraine (Ord.).

Streptorhynchus (Strophomena) vetusta James, Cincinnati Quart. Jour. Sci., I, 1874, p. 241.

Streptorhynchus vetusta Mickelborough and Wetherby, Jour. Cincinnati Soc. Nat. Hist., I, 1878, p. 76.—James, The Paleontologist, 2, 1878, p. 15.

Loc. Upper part of Cincinnati group in Ohio and Indiana.

Strophomena winchelli Hall and Clarke. Trenton (Ord.).

Streptorhynchus (Strophonella?) deltoidea Hall (non Leptæna deltoidea 1847), Second Ann. Rep. N. Y. State Geol., 1883, pl. 39, figs. 10, 12–14 (non fig. 11=S. nutans).

Strophomena winchelli Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 344, pl. 9, figs. 10, 12–14; pl. 20, fig. 26.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 394, pl. 31, fig. 11.

Loc. Janesville, Clifton, and Oshkosh, Wisconsin.

Strophomena wisconsinensis Whitfield. Lorraine (Ord.).

Strophomena wisconsinensis Whitfield, Geol. Wisconsin, IV, 1882, p. 263, pl. 12, figs. 11–13.

Strophomena winconsinensis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 251, pl. 11A, figs. 1, 2.

Loc. Delafield, Wisconsin.

Strophomena woolworthana Hall=Orthothetes woolworthana.

STROPHONELLA Hall. Genotype Strophomena semifasciata Hall.

Strophonella Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 153;—Eleventh Rep. Indiana State Geologist, 1882, p. 291.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 290;—Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 282.

Strophonella ampla Hall. Upper Helderberg (Dev.).

Strophomena (Strophodonta) ampla Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 111, figs. 1, 2.

Strophomena ampla Billings, Canadian Jour. Sci. Arts, VI, 1861, p. 345, figs. 119, 120;—Geol. Canada, 1863, p. 367, figs. 376, 378.

Strophodonta ampla Hall, Pal. New York, IV, 1867, p. 93, pl. 14, fig. 1.

Strophonella ampla Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 154;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 43, figs. 13–15.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 293, pl. 12, figs. 13–15.

Loc. Albany and Schoharie counties, Cherry Valley, Williamsville, etc., New York; Columbus, Ohio; Ontario, Canada.

Obs. Compare with S. schohariensis (Castelnau).

Strophonella cælata Hall. Chemung (Dev.).

Strophodonta cælata Hall, Pal. New York, IV, 1867, p. 112, pl. 19, figs. 6, 7.

Strophonella cælata Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 154;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 43, fig. 21.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 293, pl. 12, fig. 21; pl. 15B, fig. 10.

Loc. Near Elmira, New York.

Strophonella cavumbona Hall. Lower Helderberg (Dev.).

Strophodonta cavumbona Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 51;—Pal. New York, III, 1859, p. 187, pl. 21, figs. 1–3.

Strophomena (Strophodonta) cavumbona Meek and Worthen, Geol. Surv. Illinois, III, 1868, p. 374, pl. 7, fig. 10.

Digitized by Google

Strophonella cavumbona Hall—Continued.

Strophomena rectilateraria Meek and Worthen, Ibidem, 1868, p. 375.

Strophonella cavumbona Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 291, 292.

Loc. Schoharie, Hudson, and Catskill, New York; Perry County, Missouri.

Obs. Probably synonymous with S. punctulifera.

Strophonella costatula Hall and Clarke. Niagara (Sil.).

Strophonella costatula Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 359, pl. 84, figs. 15, 16.

Loc. Louisville, Kentucky.

Strophonella (?) conradi Hall. Lower Helderberg (Dev.).

Strophomena conradi Hall, Pal. New York, III, 1859, p. 194, pl. 16, figs. 13, 14.

Strophonella? conradi Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 292.

Loc. Schoharie, New York.

Strophonella crassa Rowley. Hamilton (Dev.).

Strophonella crassa Rowley, American Geologist, XIII, 1894, p. 153, figs. 4–6.

Loc. Callaway County, Missouri.

Strophonella geniculata (Hall). Lower Helderberg (Dev.).

Strophodonta geniculata Hall, Pal. New York, III, 1859, p. 483, pl. 23, fig. 6.

Loc. Cumberland, Maryland.

Strophonella headleyana Hall. Lower Helderberg (Dev.).

Strophomena (Strophodonta) headleyana Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 49, figs. 1, 2.

Strophodonta headleyana Hall, Pal. New York, III, 1859, p. 185, pl. 20, figs. 1–3.—Meek, American Jour. Sci., 2d ser., XL, 1865, p. 33.

Strophonella headleyana Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 292.

Loc. Schoharie, Hudson, etc., New York; Kennedy Channel and Cape Frazire, Arctic regions.

Strophonella leavenworthana Hall. Lower Helderberg (Dev.).

Strophomena (Strophodonta) leavenworthana Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 53.

Strophodonta leavenworthana Hall, Pal. New York, III, 1859, p. 189, pl. 21, figs. 5–7; pl. 23, figs. 1–3.

Strophonella leavenworthana Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879, p. 154;—Second Ann. Rep. N. Y. State Geol., 1883, pl. 43, figs. 6–9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 292, pl. 12, figs. 6–9.

Loc. Albany and Schoharie counties, New York.

Strophonella (?) patenta Hall. Clinton (Sil.).

Leptæna patenta Hall, Pal. New York, II, 1852, p. 60, pl. 21, fig. 3.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 823, fig. 631.

Strophomena patenta Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 115, pl. 5, fig. 10.—Foerste, Bull. Denison Univ., II, 1887, p. 105, pl. 8, figs. 34–37;—Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 300, pl. 5, fig. 22.

Streptorhynchus patenta Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 42, figs. 16–18.

Strophomena ? (Strophonella?) patenta Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 291, 292, pl. 9A, figs. 16–18.

Strophomena (Strophonella) patenta Foerste, Geol. Ohio, VII, 1895, p. 569, pl. 27, figs. 35–37.

Loc. Reynales Basin, Medina, etc., New York; Dayton, Ohio; Hanover, Indiana; Collinsville, Alabama.

Digitized by Google

ctulifera (Conrad). Lower Helderberg. (Dev.).

tulifera Conrad, Second Rep. N. Y. Geol. Survey, 1838, pp. 112, 117.
euglypha Conrad, Fifth Rep. N. Y. Geol. Survey, 1841, p. 36.—
il. Fauna d. West. Tennessee, 1860, p. 66, pl. 5, fig. 3.—Etheridge,
ır. Geol. Soc. London, XXXIV, 1878, p. 597.
punctulifera Vanuxem, Geol. N. Y.; Rep. Third. Dist., 1842, p. 122,
gers, Geol. Pennsylvania, II, Pt. II, 1858, p. 825, fig. 648.—Billings,
land Soc. Nat. Hist., 1863, p. 108, pl. 3, fig. 2;—Geol. Canada, 1863,
448;—Pal. Fossils, II, 1874, p. 31, pl. 3, fig. 2.
(Strophodonta) punctulifera Hall, Tenth Rep. N. Y. State Cab. Nat.
, p. 50, fig. 1.
punctulifera Hall, Pal. New York, III, 1859, p. 188, pl. 21, fig. 4; pl.
'.—Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 121, pl. 13, fig. 10.
punctulifera Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist.,
;—Second. Ann. Rep. N.Y. State Geol., 1883, pl. 43, figs. 10–12.—Hall
e, Pal. New York, VIII, Pt. I, 1892, p. 292, pl. 12, figs. 10–12.
nd Schoharie counties, New York; Square Lake, Maine; Pennsyl-
catur County, Tennessee; Dalhousie, New Brunswick, and Gaspé,
Eureka district, Nevada; Cape Hilgard and Cape Louis Napoleon,
ions.
vumbona Hall.

radiata (Vanuxem). Lower Helderberg (Dev.).

radiata Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 122, fig.
Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 50, fig. 1;—Pal.
, III, 1859, p. 193, pl. 21, figs. 8, 9; pl. 18, fig. 3.
us radiatus Miller, American Pal. Fossils, 1877, p. 134.
adiata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 292.
Albany, and Schoharie counties, New York.

ersa Hall. Chemung (Dev.).

reversa Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 494, pl. 3, fig. 4.
hybrida Hall and Whitfield, Twenty-third Rep. N. Y. State Cab.
, 1873, p. 239.
eversa Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., 1879,
all and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 293, pl. 12, figs.

(Strophodonta) reversa Hall, Second Ann. Rep. N. Y. State Geol.,
3, figs. 16–20.
, Iowa; Naples, New York.

hariensis (Castelnau). ? Upper Helderberg (Dev.).

iensis Castelnau Essai Syst. Sil. l'Amérique Septentrionale, 1843,
4, fig. 5.
, New York.
with S. ampla.

ifasciata Hall. Niagara (Sil.).

(Strophodonta?) semifasciata Hall, Trans. Albany Inst., IV, 1863,

emifasciata Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist.,
4, pl. 22, figs. 1–3; pl. 23, figs. 7, 8;—Eleventh Rep. Indiana State
, p. 292, pl. 22, figs. 1–3; pl. 23, figs. 7, 8;—Second Ann. Rep. N. Y.
., 1883, pl. 43, figs. 4, 5.—Hall and Clarke, Pal. New York, VIII, Pt.
12, figs. 4, 5.
Indiana; Wisconsin.

Digitized by Google

Strophonella striata Hall. Niagara (Sil.).

Strophomena striata Hall, Geol. N. Y.; Rep. Fourth Dist., 1843, p. 104, fig. 3;—Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 82.

Strophodonta striata Hall, Twenty-eighth Rep., Ibidem, 1879, p. 152, pl. 23, figs. 1-6;—Eleventh Rep. Indiana State Geol., 1882, p. 290, pl. 23, figs. 1-6.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 149.

Leptæna striata Hall, Pal. New York, II, 1852; p. 259, pl. 53, fig. 7.

Strophodonta (Strophonella?) striata Hall, Second Ann. Rep. N. Y. State Geol., 1883, pl. 43, figs. 1-3.

Strophonella striata Beecher and Clarke, Mem. N. Y. State Mus., I, 1889, p. 25, pl. 3, figs. 1-8.

Strophomena hanoverensis Foerste, Proc. Boston Soc. Nat. Hist., XXIV, 1890, p. 301, pl. 6, fig. 1.

Strophonella (Amphistrophia) striata Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 292, pl. 12, figs. 1-3.

Strophomena (Orthothetes) hanoverensis Foerste, Geol. Ohio, VII, 1895, p. 567, pl. 27, fig. 34; pl. 31, fig. 1.

Loc. Lockport, New York; Waldron and Hanover, Indiana; Louisville, Kentucky.

Syntrielasma Meek and Worthen=Enteletes.

SYNTROPHIA Hall and Clarke. Genotype Triplesia lateralis Whitfield.

Syntrophia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 270;—Ibidem, Pt. II, 1893, p. 216;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 836.

Syntrophia arachne (Billings). Upper Cambrian.

Stricklandia? arachne Billings, Pal. Fossils, I, 1862, p. 85, fig. 77.

Syntrophia arachne Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 216.

Loc. Point Levis, Canada.

Syntrophia arethusa (Billings). Upper Cambrian.

Stricklandinia? arethusa Billings, Pal. Fossils, I, 1862, p. 85, fig. 78.

Syntrophia arethusa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 216.

Loc. Point Levis, Canada.

Syntrophia (?) armanda (Billings). Upper Cambrian.

Orthis? armanda Billings, Pal. Fossils, I, 1865, p. 303, fig. 293.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 217.

Loc. Phillipsburg, Canada.

Obs. This species may prove to be a Billingsella. In the interior of the ventral valve "the dental plates seem to form an imperfect triangular chamber" (Billings). If there is present a true spondylium and the foramen is "apparently open" O. armanda will prove to be more nearly related to Syntrophia than to any other genus. If, however, there is present only an imperfect triangular chamber and the foramen closed by a deltidium, then the species is probably a Billingsella.

Syntrophia barabuensis (A. Winchell). Upper Cambrian.

Orthis barabuensis A. Winchell, American Jour. Sci., 2d ser., XXXVII, 1864, p. 228.

Leptæna barabuensis Whitfield, Ann. Rep. Geol. Survey Wisconsin, 1877, p. 60;—Geol. Wisconsin, IV, 1882, pp. 171, 195, pl. 1, figs. 6, 7; pl. 3, fig. 6.

Syntrophia barabuensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 216.

Loc. Near Baraboo, Wisconsin.

Syntrophia calcifera (Billings). Upper Cambrian.

Camarella calcifera Billings, Canadian Nat. Geol., VI, 1861, p. 318, fig. 3;—Geol. Canada, 1863, p. 231, fig. 247;—Pal. Fossils, I, 1865, p. 220.—Meek, Sixth Ann. Rep. U. S. Geol. Survey Terr., 1873, p. 464.

Digitized by Google

fera (Billings)—Continued.
ifera Walcott, Mon. U. S. Geol. Survey, VIII, 1884, p. 75, pl. 11,

lcifera Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 270.
) calcifera Hall and Clarke, Ibidem, VIII, Pt. II, 1893, p. 218, pl. 62,

vis and Phillipsburg, Canada; Cow Head, Newfoundland; near
ity, Utah; Eureka district, Nevada; Carter County, Missouri

alis (Whitfield). Calciferous (Ord.).
ralis Whitfield, Bull. American Mus. Nat. Hist., 1886, p. 303, pl. 24,

teralis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 270;—
III, Pt. II, 1893, p. 216, pl. 62, figs. 1–10.
sin, Vermont.

ordialis (Whitfield). Upper Cambrian.
nordialis Whitfield, Ann. Rep. Geol. Survey Wisconsin, 1877, p.
Wisconsin, IV, 1882, p. 172, pl. 10, figs. 1, 2.
nordialis Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 271.
imordialis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 218.
ounty, Wisconsin.

IS A. Winchell. Genotype Spirifer carteri Hall.
A. Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 6.—
dem, 1865, p. 275;—Pal. Ohio, II, 1875, p. 288.—White, Wheeler's
ey west 100th Merid., IV, 1875, p. 90.—Herrick, Bull. Denison Univ.,
p. 14.—Schuchert, Ninth Ann. Rep. N. Y. State Geol., 1890, p. 28.—
Clarke, Pal. New York, VIII, Pt. II, 1893, p. 47;—Thirteenth Ann.
. State Geologist, 1895, p. 760.

alta Schuchert=Cyrtia alta.

ngulata Simpson. Waverly (L. Carb.).
angulata Simpson, Trans. American Phil. Soc., n. ser., XVI, 1889,
. 5.—Schuchert, Ninth Ann. Rep. N. Y. State Geol., 1890, p. 32.
Pennsylvania.

rteri (Hall). Waverly and Burlington (L. Carb.).
ri Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 170.—Meek
Pal. Ohio, II, 1875, p. 285 (not his figures=S. texta Hall).
tia?) hannibalensis Swallow, Trans. St. Louis Acad. Sci., I, 1860,

typa Winchell, Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 7;—
Phil. Soc., XII, 1870, p. 252.—Hall and Clarke, Pal. New York, VIII,
3, pp. 8, 48, 50, pl. 26, figs. 6, 7, 10; pl. 27, figs. 1–3.
datus Meek, Proc. Acad. Nat. Sci., Philadelphia, 1865, p. 275;—Am.
2d ser., XLIII, 1867, p. 407.
datus ? Meek, U. S. Geol. Expl., 40th Parl., IV, 1877, p. 87.
cuspidatus Walcott (non Martin), Mon. U. S. Geol. Survey, VIII,
9, pl. 3, fig. 11.—Herrick (partim), Bull. Denison Univ., III, 1888, p.
g. 7; pl. 2, fig. 17 (non pl. 5, figs. 4–7=S. herricki).
carteri Schuchert, Ninth Ann. Rep. N. Y. State Geol., 1890, p. 30.—
ol. Survey Missouri, V, 1895, p. 87, pl. 40, fig. 10.
typa Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 48, fig. 40.
hannibalensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895,
s. 33–35.
County and Bedford, Ohio; Burlington, Iowa; Marion and Pike,
Missouri; White Pine and Eureka districts, Nevada; near Clen-
ontana.

Digitized by Google

Syringothyris cuspidatus Walcott, and Herrick=S. carteri.

Syringothyris extenuata (Hall). Waverly (L. Carb.).

Spirifer extenuatus Hall, Geol. Survey Iowa, I, Pt. II, 1858, p. 520, pl. 7, fig. 6.—White, Wheeler's Expl. and Surv. west 100th Merid., 1875, p. 88, pl. 5, fig. 9.

Syringothyris halli A. Winchell, Proc. Acad. Nat. Sci. Philadelyhia, 1863, p. 8.

Syringothyris extenuata Schuchert, Ninth Ann. Rep. N. Y. State Geol., 1890, p. 33.—Keyes, Geol. Survey Missouri, V, 1895, p. 86.

Loc. Burlington, Iowa; Clarksville, Missouri; Battlecreek, Michigan; Mountain Spring, Nevada.

Syringothyris gigas (Troost). Subcarboniferous.

Cyrtia gigas Troost, Sixth Geol. Report Tennessee, 1841, p. 12.

Syringothyris gigas Schuchert, Ninth Ann. Rep. N. Y. State Geol., 1890, p. 33.

Loc. Harpeth River, Tennessee.

Syringothyris halli Winchell=S. carteri extenuata.

Syringothyris herricki Schuchert. Waverly (L. Carb.).

Syringothyris cuspidatus Herrick (partim), Bull. Denison Univ., III, 1888, pl. 5, figs. 4–7 (not pls. 1, 2).

Syringothyris herricki Schuchert, Ninth Ann. Rep. N. Y. State Geologist, 1890, p. 36.—Herrick, Geol. Ohio, VII, 1895, pl. 21, figs. 4–7.

Loc. Granville, Ohio.

Syringothyris missouri Hall and Clarke. Chouteau (L. Carb.).

Syringothyris missouri Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 363, pl. 39, figs. 29–31.

Loc. Chouteau Springs, Missouri.

Syringothyris (?) plena (Hall). Burlington (L. Carb.).

Spirifer plena Hall, Geol. Survey Iowa, I, 1858, p. 603, pl. 13, fig. 4.

Syringothyris? plena Schuchert, Ninth Ann. Rep. N. Y. State Geologist, 1890, p. 37.

Spirifer plenus Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, pp. 31, 39, 48, pl. 37, figs. 32, 33.

Syringothyris plena Keyes, Geol. Survey Missouri, V, 1895, p. 88, pl. 40, fig. 8.

Loc. Burlington, Iowa; Hannibal, Missouri; Quincy, Illinois.

Syringothyris randalli Simpson. Waverly (L. Carb.).

Syringothyris randalli Simpson, Trans. American Phil. Soc., n. ser., XVI, 1889, p. 441, fig. 6.—Schuchert, Ninth Ann. Rep. N. Y. State Geologist, 1890, p. 36.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 50, pl. 27, figs. 13–16.

Loc. Near Warren and Union City, Pennsylvania.

Syringothyris texta (Hall). Waverly to Keokuk (L. Carb.).

Spirifer cuspidatus Yandell and Shumard, Cont. Geol. Kentucky, 1847, pp. 19, 21.

Spirifer textus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 169.—White, Second Ann. Rep. Indiana Bureau Statistics and Geol., 1880, p. 512, pl. 7, figs. 1, 2;—Tenth Rep. Indiana State Geol., 1881, p. 144, pl. 7, figs. 1, 2.

Spirifer subcuspidatus Hall, Geol. Survey Iowa, I, 1858, p. 646, pl. 20, fig. 5;—Pal. New York, IV, 1867, p. 249.

Spirifer propinquus Hall, Geol. Survey Iowa, I, 1858, p. 647.—Meek and Worthen, Geol. Survey Illinois, 1868, III, p. 530, pl. 19, fig. 8.

Spirifer carteri Meek (partim), Pal. Ohio, II, 1875, pl. 14, fig. 7.

Spirifer cuspidatiformis Miller, North American Geol. Pal., 1889, p. 372.

Syringothyris texta Schuchert, Ninth Ann. Rep. N. Y. State Geol., 1890, p. 34.—Keyes, Geol. Survey Missouri, V, 1895, p. 88.

Syringothyris subcuspidatus and texta Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 50, pl. 26, figs. 8, 11 (?9, 12); pl. 27, figs. 4–12, 18.

Loc. New Albany and New Providence, Indiana; near Louisville, Kentucky; Sciotoville, Ohio; Keokuk, Iowa; Warsaw and Nauvoo, Illinois.

Digitized by Google

ypa Winchell=S. carteri.

A d'Orbigny.

rebratula chilensis Brod.=Terebratula dorsata Gmelin.

'Orbigny, Pal. Franc. Ter. Cret., IV, 1847, p. 110.—Dall, American ch., VI, 1870, p. 115.—Beecher, Trans. Connecticut Acad., IX, 1893,

fornica Stanton. Upper Cretaceous (Knoxville).

alifornica Stanton, Bull. U. S. Geol. Survey, 133, 1896, p. 33, pl. 1,

ood Creek, Tehama County, California.

dubitanda (Cooper). ?Upper Cretaceous.

tanda Cooper, Bull. California State Mining Bureau, 4, 1894, p. 50, 48, 49.

nd Point Loma, California.

mbricata (Cooper). ?Upper Cretaceous.

icata Cooper, Bull. California State Mining Bureau, 4, 1894, p. 51, 50, 51.

California.

a Gabb. Cretaceous (Chico).

besa Gabb, Geol. Survey California, Pal., I, 1864, p. 205, pl. 26,

obesa Whiteaves, Mesozoic Fossils, Geol. Survey Canada, I, 1884,

at, Placer County, California; Queen Charlotte Island.

ata (Say). Cretaceous.

icata Say, American Jour. Sci., II, 1820, p. 43;—Jour. Acad. Nat. delphia, VI, 1829, p. 73, pl. 3, figs. 5, 6.

yi Morton, Syn. Cret. United States, 1834, p. 71, pl. 3, figs. 3, 4;—Jour. Sci., XLVIII, 1845, p. 283.

licata d'Orbigny, Prod. Pal., 1849, p. 259.—Gabb, Proc. American VIII, 1861, p. 193.—Credner, Zeitscr. d. Deuschen Geol. Gessel., 24.—Whitfield, Mon. U. S. Geol. Survey, IX, 1885, p. 12, pl. 1,

ey.

uxemi (Lyell and Forbes). Cretaceous.

nuxemiana Lyell and Forbes, Proc. Geol. Soc. London, 1844, p. 308, es.

anuxemi Lyell and Forbes, Quart. Jour. Geol. Soc. London, I, , with figures.

anuxemiana d'Orbigny, Prod. Pal., 1849, p. 259.—Gabb, Proc. Acad. Philadelphia, 1861, p. 19;—Proc. American Phil. Soc., VIII, 1861, Whitfield, Mon. U. S. Geol. Survey, IX, 1885, p. 14, pl. 1, figs. 1–4.

anuxemi Hollick, Trans. N. Y. Acad. Sci., XI, 1892, p. 98, pl. 1,

ey; Tottenville, Staten Island.

itneyi Gabb=Rhynchonella whitneyi.

A Llhwyd. Genotype T. perovalis Sowerby.

lhwyd, Lithophylacii Britannici Ichnographia, 1696.—Hall, Pal. , IV, 1867, p. 386.—Dall, American Jour. Conch., VI, 1870, p. 101.—, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 153.

igma d'Orbigny=Rhynchonella ænigma.

Digitized by Google

Terebratula ænigma Darwin=Rhynchonella anduin.
Terebratula acuminatissima Castelnau=Spirifer acuminatus.
Terebratula andii d'Orbigny=Enteletes andii.
Terebratula antissiensis d'Orbigny=Rhynchonella antissiensi
Terebratula atlantica Morton=Terebratulina atlantica.
Terebratula arcuata Swallow (non Roemer)=Dielasma shuma

Terebratula augusta Hall and Whitfield. Triassic-

Terebratula augusta Hall and Whitfield, King's U. S. Geol. Expl. 40th 1877, p. 285, pl. 7, figs. 7–10.—White, Bull. U. S. Geol. Survey 1880, p. 108;—Twelfth Ann. Rep. U. S. Geol. Survey Terr., 1883, p

Loc. Shoshone Springs, Nevada; Triassic, southwestern Idaho.

Terebratula bicanaliculata Schlotheim.

Terebratula bicanaliculata Schl., Mém. Soc. Géol. France, 2d ser, IV, pl. 8, figs. 17–19.

Terebratula cornuta Burmeister and Geibel, Abh. Naturf. Gessel. Hall p. 127.

Loc. Europe; Dona Ana, Chile.

Terebratula bisacula McChesney. Kaskaskia (

Terebratula bisacula McChesney, Descriptions New Fossils, 1861, p. 8

Loc. Chester and Golconda, Illinois.

Terebratula borealis Castelnau=Clitambonites borealis.
Terebratula bovidens Morton=Dielasma bovidens.

Terebratula brevilobata Swallow. Warsaw (I

Terebratula brevilobata Swallow, Trans. St. Louis Acad. Sci., II, 186

Loc. Ste. Genevieve County, Missouri.

Terebratula burlingtonensis White=Dielasma burlingtonensis
Terebratula camila Morton=T. harlani.

Terebratula canipes Ravenel. Jackson (

Terebratula canipes Ravenel, Proc. Acad. Nat. Sci. Philadelphia, II, 18 Conrad, American Jour. Conch., I, 1865, p. 15.

Loc. South Carolina.

Terebratula carneoidea Guppy.

Terebratula carneoidea Guppy, Quart. Jour. Geol. Soc. London, X p. 296, pl. 19, fig. 2.

Loc. San Fernando, Trinidad.

Obs. May be the same as living Terebratula cubensis Pourtales (Dall)= sphenoidea (Philippi). The latter also occurs fossil in the P Calabria and Sicily (Davidson).

Terebratula chiliensis d'Orbigny. Qua

Terebratula chilensis d'Orbigny, Voyage dans l'Amérique Mérid., p. 163.

Loc. Coquimbo, Chile.

Terebratula choctawensis Shumard=Kingina wacoensis.
Terebratula concinna Bayle and Coquand=Rhynchonella æni
Terebratula cooperensis Miller=Seminula parva.

Terebratula copiapensis Möricke.

Terebratula copiapensis Möricke, Neues Jahrb. f. Mineral., Beilage 1894, p. 63, pl. 2, figs. 5a–5c.

Loc. Quebrada de Maricunga, Chile.

Digitized by Google

issirostris Conrad. Eocene.
emissirostra Conrad, Kerr's Geol. North Carolina, App. A, 1875,
, fig. 1.
ton, North Carolina.

yana Rathbun. Middle Devonian.
erbyana (Hartt MS.) Rathbun, Bull. Buffalo Soc. Nat. Hist., I,
6, pl. 10, figs. 15, 17, 22, 24, 25.—Rathbun, Proc. Boston Soc. Nat.
1879, p. 35.
ovince of Para, Brazil.

eykana Bayle and Coquand. Jurassic.
omeykana Bayle and Coquand, Mém. Soc. Géol. France, 2d ser.,
. 30, pl. 8, figs. 1–3.—Burmeister and Geibel, Abh. Naturf. Gessel.
1862, p. 126.—Möricke, Neues Jahrb. f. Mineral., Beilageband, IX,
.
la Ternera, Dona Ana, and Juntas, Chile.

nbergi Felix. Upper Jurassic.
orenbergi Felix, Palæontographica, XXXVII, 1891, p. 176, pl. 27,
Titania, Oaxaco, Mexico.

Hall. Middle Devonian.
ia Hall, Pal. New York, IV, 1867, p. 390, pl. 60, figs. 26–28.
, Iowa.

ngata of American authors=Dielasma bovidens.

rginata Sowerby. Jurassic.
narginata (Sowerby) Bayle and Coquand, Mém. Soc. Géol. France,
, 1851, p. 32, pl. 8, figs. 7–9.
Dona Ana, Chile.

des Bayle and Coquand. Jurassic.
coides Bayle and Coquand, Mém. Soc. Géol. France, 2d ser., IV,
, pl. 8, figs. 20–22.
, Chile.

idana Morton=Terebratulina floridana.
mosa Hall=Dielasma formosum.
gilis Morton=Terebratula harlani.
ndryi d'Orbigny=Enteletes gaudryi.
niculosa McChesney=Dielasma bovidens.
ssa Conrad=Terebratulina atlantica.
byi Miller=Dielasma gorbyi.

schei Steinman. Jurassic.
ottschii Steinman, Neues Jahrb. f. Min., Beilageband, 1881, p. 252,
. 7, 8.
, Bolivia.

acilis Swallow (non Von Buch)=T. swallovana.
adalupæ Roemer=Terebratulina guadalupæ.
liana Gabb=Terebratulina atlantica.

ani Morton. Upper Cretaceous.
arlani Morton, American Jour. Sci., XVIII, 1829, p. 250, pl. 3, fig.
m, XVII, 1829, p. 283;—Jour. Acad. Nat. Sci. Philadelphia, VI,
, pl. 3, figs. 1–4, 7, 8;—Syn. Cret. U. S., 1834, p. 70, pl. 3, fig. 1; pl. 9,

Digitized by Google

Terebratula harlani Morton—Continued.

figs. 2, 8, 9.—Gabb, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 18;—Proc. American Phil. Soc., VIII, 1861, p. 196.—Credner, Zeit. d. Deutschen Geol. Gessel, 1870, p. 221.—Whitfield, Mon. U. S. Geol. Survey, IX, 1885, p. 6, pl. 1, figs. 15–23.

Terebratula fragilis Morton (non Schloth.), Jour. Acad. Nat. Sci. Philadelphia, VI, 1829, p. 75, pl. 3, figs. 3, 4;—American Jour. Sci., XVIII, 1829, p. 250, pl. 3, fig. 17;—Ibidem, XVII, p. 283;—Syn. Cret. U. S., 1834, p. 70, pl. 3, fig. 2.

Terebratula perovalis Morton (non Sowerby), Jour. Acad. Nat. Sci. Philadelphia, VI, 1829, p. 77, pl. 3, figs. 7, 8.

Terebratula camilla Morton, Syn. Cret. U. S., 1834, p. 70, in text.

Terebratula harlani var. discoidea Morton, Syn. Cret. U. S., 1833.

Terebratula harlani var. rectilatera Morton, Ibidem.

Terebratula subfragilis d'Orbigny, Prod. Pal., II, 1849, p. 258.

Terebratula atlantica (non Morton) Gabb, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 18.

Loc. New Jersey; Delaware and South Carolina.

Terebratula harmonia Hall=Eunella harmonia.

Terebratula hastata of American authors=Dielasma bovidens.

Terebratula helena Whitfield. Upper Cretaceous.

Terebratula helena Whitfield, Lndlow's Rep. Black Hills Dakota, 1875, p. 103, figs. 5–10.

Loc. North of Belle Fourche, South Dakota.

Terebratula hochstetteri Toula=Dielasma hochstetteri.

Terebratula hohmanni Möricke. Jurassic.

Terebratula hohmanni Möricke, Neues Jahr. f. Mineral., Beilageband, IX, 1894, p. 64, pl. 6, figs. 4a, 4b.

Loc. Quebrada de Maricunga, Chile.

Terebratula humboldtensis Gabb. Triassic.

Terebratula humboldtensis Gabb, Geol. Survey California, Pal., I, 1864, p. 34, pl. 6, fig. 35.—Hall and Whitfield, King's U. S. Geol. Expl. 40th Parl., IV, 1877, p. 282, pl. 6, figs. 22–24.—Whiteaves, Cont. Canadian Pal., I, 1889, p. 129.

Loc. Star Canyon, Humboldt County, and Dun Glen Pass, Pah-Ute Range, Nevada; Nicola Lake, Canada.

Terebratula ignaciana d'Orbigny. Jurassic.

Terebratula ignaciana d'Orbigny, Voyage dans l'Amérique Mérid., Pal., 1842, p. 63, pl. 22, figs. 14, 15.—Darwin, Geological Observations on South America, 1846, p. 216.

Loc. Cordillere du Chili, South America.

Terebratula inca Forbes=T. perovalis.

Terebratula inconstans Herrick=Cryptonella inconstans.

Terebratula inornata McChesney. "Keokuk to Coal Measures."

Terebratula inornata McChesney, New Pal. Fossils, 1860, p. 48.

Loc. Sangamon County, Illinois.

Terebratula itaitubensis Derby=Dielasma itaitubense.

Terebratula jucunda Hall. Middle Devonian.

Terebratula jucunda Hall, Pal. New York, IV, 1867, p. 390, pl. 60, figs. 29–31.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 154.

Loc. Waterloo, Iowa; Jefferson and Clark counties, Indiana.

Terebratula lachryma Morton=Terebratulina lachryma.

Digitized by Google

unosa Schl. Jurassic.
lacunosa (Schl.) Bayle and Coquand, Mém. Soc. Géol. France, ser. ii, p. 29, pl. 3, figs. 10, 11.
Dona Ana, Chile.

illus Morton. Coal Measures.
apillus Morton, American Jour. Sci., XXIX, 1836, p. 153, pl. 26, fig. 36.
Furnace, Scioto County, Ohio.
rminable.

ta Guppy. Eocene.
ecta Guppy, Quart. Jour. Geol. Soc. London, XXII, 1866, p. 296, pl.

nando, Trinidad.

ns Hall=Cryptonella lens.

onensis Conrad=Kingena leonensis.

rdensis Whiteaves. Triassic.
liardensis Whiteaves, Cont. Canadian Pal., I, 1889, p. 130, pl. 17, Abstract of same pub. 1888.)
iver, Canada.

ncklæni Hall=Eunella lincklæni.

arcyi Shumard=Eumetria marcyi.

ridionalis Conrad. Oolite or Cretaceous.
meridionalis Conrad, U. S. Astronomical Exped. to the Southern ere, 1855, p. 282, pl. 42, fig. 10.
ra de Dona Ana, Chile.

sogona Castelnau. Formation.?
nesogona Castelnau (non Phillips), Essai Syst. Sil. l'Amérique Sep le, 1843, p. 40, pl. 13, fig. 3.
of Quebec, Canada.
minable.

xicana Hall. ?Upper Carboniferous.
nexicana Hall, Emory's Rep. U. S. and Mexican Bound. Survey, I, 20, fig. 2.
en.
ed. Compare with Seminula argentea.

llipunctata Hall=Dielasma bovidens.

ormoni Marcou=Hustedia mormoni.

avicella Hall=Centronella navicella.

ens Conrad. Miocene.
nitens Dana, Wilkes's U. S. Exped., X, 1849, p. 726, pl. 19, fig. 1.
s earlier description I have not found.)
a nitans Conrad, American Jour. Conch., 1865, p. 154.

ciformis Morton. Coal Measures.
nuciformis Morton, American Jour. Sci., XXIX, 1836, p. 150, pl. 2,

Hill east of Flint Ridge, Ohio.
ned so as to be recognizable.

ucula Sowerby=Rhynchonella nucula.

cidentalis Miller=Dielasma occidentale.

oides Eaton=Rensselæria ovoides.

Digitized by Google

Terebratula ontario Hall. Hamilton (Dev.).

Terebratula ontario Hall, Pal. New York, IV, 1867, p. 418, pl. 60, figs. 45–48.

Loc. Canandaigua Lake, New York.

Terebratula ornithocephala Bayle and Coquand=T. subovoides.

Terebratula parva Swallow=Seminula parva.

Terebratula patagonica Sowerby. Tertiary.

Terebratula patagonica Sowerby, Darwin's Geol. Observations on South America, 1846, p. 252, pl. 2, fig. 25.

Loc. St. Josef and St. Julian, Patagonia.

Terebratula pennata Atwater=Spirifer pennatus.

Terebratula (Zeilleria) perforata Piette. Jurassic.

Terebratula (Zeilleria) perforata (Piette) Möricke, Neues Jahrb. f. Mineral., Beilageband, IX, 1894, p. 65.

Loc. Europe; Sierre de la Ternera, Chile.

Terebratula perinflata Shumard. Upper Carboniferous.

Terebratula perinflata Shumard, Trans. St. Louis Acad. Sci., I, 1859, p. 392.

Loc. Guadalupe Mountains, Texas.

Terebratula perovalis Eaton (non Sowerby)=Rensselæria ovoides.

Terebratula perovalis Morton (non Sowerby)=T. harlani.

Terebratula perovalis Sowerby. Jurassic.

Terebratula inca Forbes, Darwin's Geol. Observations S. America, 1846, p. 268, pl. 5, figs. 19–20.

Terebratula perovalis Bayle and Coquand, Mém. Soc. Géol. France, ser. ii, IV, 1851, p. 22, pl. 8, figs. 15, 16.—Gottsche, Palæontographica, Suppl., III, 1878, p. 33, pl. 4, fig. 9.—Steinman, Neues Jahrb. f. Min., Beilageband, I, 1881, p. 252.—Möricke, Ibidem, Beilageband, IX, 1894, p. 65, pl. 3, figs. 6a–6c.

Loc. Europe; Manflas, Tres Cruces, Iquique, and Espinazito, Chile; Caracoles, Bolivia.

Terebratula peruviana d'Orbigny=Seminula argentea.

Terebratula planirostra Hall=Cryptonella planirostris.

Terebratula planosulcata Meek and Worthen=Cleiothyris roissyi.

Terebratula plicata Say=Terebratella plicata.

Terebratula poeyana Lea. ?Jurassic.

Terebratula poeyana Lea, Trans. American Phil. Soc., n. ser., VII, 1841, p. 260, pl. 10, fig. 13.

Loc. Habana, Cuba.

Terebratula prisca=Atrypa reticularis.

Terebratula punctata Sowerby. Liassic.

Terebratula punctata Sowerby, Mineral Conch., I, 1812, p. 46, tab. 15, fig. 4.—Davidson, British Oolitic and Liassic Brach., Pal. Soc., 1852, p. 45.—Burmeister and Geibel, Abh. Naturf. Gessel. Halle, VI, 1862, p. 127.

Terebratula cfr. punctata Behrendsen, Zeit. der. Deutschen Geol. Gessel., XLIII, 1891, p. 395.

Terebratula (Waldheimia) punctata (Sowerby) Möricke, Neues Jahrb. f. Mineral., Beilageband, IX, 1894, p. 66.

Loc. Europe; Portezuelo Ancho, Argentine Republic; Manflas, Juntas, Chile.

Terebratula raimondiana Gabb. ?Cretaceous.

Terebratula raimondiana Gabb, Jour. Acad. Nat. Sci. Philadelphia, 2d ser., VIII, 1881, p. 298, pl. 42, fig. 9.

Loc. Near Ollon, Peru.

Digitized by Google

ticularis=Atrypa reticularis.
ctirostra Hall=Cryptonella rectirostris.
ellini d'Orbigny. Jurassic.
epellini Anguilera, Datos para la Geologia de Mexico, 1893, p. 18.
Mexico.
usta Whiteaves. Jurassic (?Cretaceous).
obusta Whiteaves, Cont. Canadian Pal., I, 1889, p. 163, pl. 22, figs.

Iountains, near Devils Lake, Canada.
zon of this locality is probably Jurassic (Stanton).
ckymontana Marcou=Pugnax rockymontana.
mingeri Hall=Cranæna romingeri.
wleyi Worthen=Dielasma rowleyi.
yssii d'Orbigny (non L'Éveillé)=Seminula argentea.
yssii Marcou=Cleiothyris roissyi.
cculus Dawson, and Davidson=Dielasma sacculus.
isimplex White. Triassic.
emisimplex White, Bull. U. S. Geol. Survey Terr., V, 1879, p. 108.
tern Idaho.

rpentina Owen=Eumetria marcyi.
umardana Miller=Dielasma shumardanum.
nulator Hall=Eunella simulator.
iriferoides Eaton=Athyris spiriferoides.
excavata Conrad. Oolite or Cretaceous.
ubexcavata Conrad, U. S. Astronomical Exped. to the Southern
ere, 1855, p. 282, pl. 41, fig. 4.
ra de Dona Ana, Chile.
bfragilis d'Orbigny=T. harlani.
ovoides Roemer. Lias (Jurassic).
rnithocephala (non Sowerby) Bayle and Coquand, Mém. Soc. Géol.
d ser, IV, 1851, p. 18, pl. 8, figs. 12-14.
subovoides Behrendsen, Zeit. der Deutschen Geol. Gessel., XLIII,
95.—Möricke, Neues Jahrb., f. Mineral., Beilageband, IX, 1894, p. 66.
Valle lenas amorillas, Rio Salado, Argentine Republic; Mine
, Manflas, and Tres Cruces, Chile.
numismalis Davidson?. Lias (Jurassic).
subnumismalis Davidson, British Oolitic and Liassic Brach., Pal.
, p. 36, pl. 51, fig. 10.
efr. subnumismalis Behrendsen, Zeit. der. Deutschen Geol. Gessel.,
91, p. 396.
Rio Salado, Argentine Republic.
retziforma McChesney. Kaskaskia (L. Carb.).
ubretziaforma McChesney, Descrip. New Fossils, 1861, p. 82.
n Bluff, Illinois.
btetrædra Conrad=Rhynchonella anduin.
btilita Hall=Seminula argentea.
llivanti Hall=Eunella sullivanti.

Digitized by Google

Terebratula swallovana Miller. Kaskaskia (L. Carb.).

Terebratula gracilis Swallow (non von Buch), Trans. St. Louis Acad. Sci., II, 1863, p. 83.

Terebratula swallovana Miller, American Pal. Foss., 2d ed., 1883, p. 299.

Loc. St. Marys, Missouri; Chester, Illinois.

Terebratula tayloriana Lea=Rhynchonella tayloriana.

Terebratula tetrædra Sowerby=Rhynchonella tetrædra.

Terebratula titicacensis Gabb=Seminula titicacaensis.

Terebratula traversensis A. Winchell. Hamilton (Dev.).

Terebratula traversensis A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 95.

Loc. Grand Traverse region, Michigan.

Terebratula trinitatensis Guppy. Eocene.

Terebratula trinitatensis Guppy, Quart. Jour. Geol. Soc. London, XXII, 1866, p. 296, pl. 19, fig. 1.

Loc. Sanfernando, Trinidad.

Terebratula trinucleus Hall=Seminula trinucleus.

Terebratula turgida Hall=Dielasma turgidum.

Terebratula turpis Verneuil=Clitambonites borealis.

Terebratula utah Marcou (non Hall and Whitfield)=Pugnax utah.

Terebratula (?) utah Hall and Whitfield. Lower Carboniferous.

Terebratula utah Hall and Whitfield, King's Geol. Expl. 40th Parl., IV, 1877, p. 258, pl. 4, fig. 18.

Loc. Cottonwood Divide, Wasatch Range, Utah.

Obs. Not well established. Based upon a single dorsal valve. May be a Dielasma.

Terebratula valenciennii Castelnau=Meristella nasuta.

Terebratula wacoensis Roemer=Kingena wacoensis.

Terebratula wilmingtonensis Lyell and Sowerby=Rhynchonella wilmingtonensis.

Terebratula (?) cfr. zieteni Loriol. Jurassic.

Terebratula cfr. zieteni Aguilera, Bol. Com. Geológica de Mexico, I, 1895, p. 1, pl. 2, figs. 6, 7.

Loc. Rancho Alamitos, Sierra de Catorce, Mexico.

TEREBRATULINA d'Orb. Genotype Anomia caputserpentis Linné.

Terebratulina d'Orbigny, Ann. Des. Sci. Nat., VIII, 1848, p. 67.—Hall and Clarke, Thirteenth Ann. Rep. N. Y. State Geol., 1895, p. 872.

Terebratulina atlantica (Morton). Upper Cretaceous.

Terebratula atlantica Morton, Jour. Acad. Nat. Sci. Philadelphia, VIII, 1842, p. 214.

Terebratula halliana Gabb, Proc. Acad. Nat. Sci. Philadelphia, V, 1861, p. 19.

Terebratulina halliana Gabb, Proc. American Phil. Soc., VIII, 1861, p. 200.

Terebratula glossa Conrad, American Jour. Conch., V, 1869, p. 42, pl. 1, fig. 22.

Terebratulina atlantica Whitfield, Mon. U. S. Geol. Survey, IX, 1885, p. 9, pl. 1, figs. 10-13.—Hollick, Trans. N. Y. Acad. Sci., XI, 1892, p. 98, pl. 1, fig. 8.

Loc. New Jersey; Tottenville, Staten Island.

Terebratulina filosa Conrad. ?Cretaceous.

Terebratulina filosa Conrad, American Jour. Conch., II, 1866, pp. 77, 105, pl. 9, figs. 4, 5.

Loc. Uniontown, Alabama.

Digitized by Google

ridana (Morton). Cretaceous.
oridana Morton, Syn. Cret. U. S., 1834, p. 72, pl. 16, fig. 17.
floridana d'Orbigny, Prod. Pal., II, 1849, p. 258.—Whitfield, Mon. Survey, IX, 1885, p. 11.
luff, Alabama.

racilis (Schlotheim). Eocene.
racilis Schlotheim, Die Petrefactenkunde, 1820, p. 270.
gracilis Conrad, American Jour. Conch., I, 1865, p. 15.
Alabama.

adalupæ (Roemer). Upper Cretaceous.
audalupæ Roemer, Texas, 1849, p. 408;—Kreidebildung von Texas, , pl. 6, fig. 3.—Gabb, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 19.
unfels, Austin, and 200 miles north in Dallas County, Texas (Hill).

halliana Gabb=T. atlantica.

chryma (Morton). (Cretaceous?) Eocene?.
achryma Morton, Syn. Cret. U. S., 1834, p. 72, pl. 10, fig. 11; pl. 16,

lachryma d'Orbigny, Prod. Pal., 1849, p. 396.—Gabb, Proc. Acad. Philadelphia, 1861, p. 19;—Proc. American Phil. Soc., VIII, 1861 p. rad, American Jour. Conch., I, 1865, p. 15.—Whitfield, Mon. U. S. vey, IX, 1885, p. 12, pl. 1, fig. 14.
sey; Claiborne, Alabama.

Hall and Clarke. Genotype T. criticus Hall and Clarke.
ll and Clarke, Pal. New York, VIII, Pt. II, 1895, explanation to

s Hall and Clarke. St. Louis (L. Carb.).
ticus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 84,

rpe.

Orbicula terminalis Sharpe (non Emmons)=T. millipunc-
l.
rpe, Quart. Jour. Geol. Soc. London, IV, 1847, p. 66.—Dall, Bull. p. Zool., III, 1871, p. 37;—Bull. U. S. Nat. Mus., 8, 1877, p. 73.—Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 138, 168.—Winchell chert, Minnesota Geol. Survey, III, 1893, p. 367.—Hall and Clarke, Ann. Rep. N. Y. State Geologist, 1894, p. 258.

uncta Ulrich. Lorraine (Ord.).
sipuncta Ulrich, American Geologist, IV, 1889, p. 22; III, p. 378,

ti, Ohio.

ri Miller. Lorraine (Ord.).
ri Miller, Cincinnati Quart. Jour. Sci., I, 1874, p. 347, fig. 39.
lyeri Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 142.
ti, Ohio.

Billings=Schizocrania filosa.

s Ulrich. Trenton (Ord.).
ilis Ulrich, American Geologist, IV, 1889, p. 21; III, p. 378, fig. 6.—Clarke, Pal. New York, VIII, Pt. I, 1892, p. 142, pl. 4G, fig. 14.
vington, Kentucky.

Digitized by Google

Trematis huronensis Billings. Black River (Ord.).

Trematis huronensis Billings, Pal. Fossils, I, 1862, p. 53, fig. 59 on p. 52;—Geol. Canada, 1863, p. 159, fig. 130.

Productella minneapolis Sardeson, Bull. Minnesota Acad. Nat. Sci., III, 1892, p. 332, pl. 4, figs. 11, 12.

Trematis huronensis? Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 368, fig. 29.

Loc. Pallideau Islands, Lake Huron; Minneapolis, Minnesota.

Trematis millepunctata Hall. Utica and Lorraine (Ord.).

Trematis millepunctata Hall, Description n. sp. Crinoidea and other Fossils, 1866, p. 14;—Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 221, pl. 7, figs. 22–25.—Hall and Whitfield, Pal. Ohio, II, 1875, p. 70, pl. 1, figs. 4–7.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 16.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 139, pl. 4G, figs. 4–10.

Loc. Cincinnati, Ohio.

Obs. See T. quincuncialis and T. reticularis.

Trematis montrealensis Billings. Trenton (Ord.).

Trematis montrealensis Billings, Pal. Fossils, I, 1862, p. 52, fig. 57;—Geol. Canada, 1863, p. 159, fig. 128.

Loc. Montreal, Canada.

Trematis oblata Ulrich. Utica and Lorraine (Ord.).

Trematis punctostriata Hall and Whitfield (non Hall, 1873), Pal. Ohio, II, 1875, p. 70, pl. 1, figs. 8, 9.

Trematis oblata Ulrich, American Geologist, IV, 1889, p. 23; III, p. 378, fig. 9.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 142, pl. 4G, fig. 20.

Loc. Cincinnati, Ohio.

Trematis ottawaensis Billings. Trenton and Lorraine (Ord.).

Trematis ottawaensis Billings, Pal. Fossils, I, 1862, p. 53, fig. 58 on p. 52;—Geol. Canada, 1863, p. 159, fig. 129;—Cat. Sil. Fossils Anticosti, 1866, p. 11.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 139, pl. 4G, figs. 15–17.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 369, fig. 30.

Loc. Ottawa, Canada; Anticosti; Trenton Falls, New York; Frankfort, Kentucky; St. Paul, Minnesota.

Trematis? pannulus White=Iphidea pannulus.

Trematis punctostriata Hall and Whitfield=T. oblata.

Trematis punctistriata Hall. Lorraine (Ord.).

Trematis punctostriata Hall, Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, p. 243, pl. 13, figs. 17, 18.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 142, pl. 4G, figs. 11–13 (?3).

Loc. Clifton, Tennessee.

Trematis (?) pustulosa Hall. Lorraine (Ord.).

Trematis? pustulosa Hall, Descrip. n. sp. Crinoidea and other Fossils, 1866, p. 15;—Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., 1872, p. 222.

Loc. Near Horicon, Wisconsin.

Trematis quincuncialis Miller and Dyer. Lorraine (Ord.).

Trematis quincuncialis Miller and Dyer, Cont. to Pal., II, 1878, p. 8, pl. 3, fig. 9.

Loc. Lebanon, Ohio.

Obs. Seems to be only a variety of T. millepunctata occurring at a higher horizon.

Digitized by Google

laris (Miller). Lorraine (Ord.).
laris Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 280, fig. 1.
lle, Indiana.
e specimens have been examined and appear to be young T. mille-

Hall=Schizocrania rudis.

alis Emmons. Trenton (Ord.).
ninalis Emmons, Geol. New York; Rep. Second Dist., 1842, p. 395,
all, Pal. New York, I, 1847, p. 100, pl. 30, fig. 11.
ninalis Emmons, American Geologist, Pt. II, 1855, p. 201, fig. 63.—
Geol. Canada, 1863, p. 159, fig. 127.—Hall and Clarke, Pal. New York,
I, 1892, p. 139, pl. 4G, figs. 1, 2.
rminalis Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 14.
ille, Trenton Falls, Watertown, and elsewhere in New York.

cata Hall=Schizobolus concentricus.

ata Ulrich. Lorraine (Ord.).
bonata Ulrich, American Geologist, IV, 1889, p. 23; III, 1889, fig. 8
—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 139, pl. 4G,
9.
on, Kentucky; Cincinnati, Ohio.

US Matthew. Genotype T. insignis Matthew.
s Matthew, Canadian Rec. Science, 1893, p. 276.—Hall and Clarke,
Ann. Rep. N. Y. State Geol., 1894, p. 252.

signis Matthew. Middle Cambrian.
s insignis Matthew, Canadian Record Science, 1893, p. 276, fig. 1;—
oyal Soc. Canada, Vol. XI, 1894, p. 88, pl. 16, fig. 4a–d;—Trans.
d. Sci., XIV, 1895, p. 122, pl. 4, fig. 2.
ins, New Brunswick.

RA Hall. Genotype Spirifer? perforatus Hall.
Hall, Pal. New York, III, 1859, p. 207;—Twelfth Rep. N. Y. State
. Hist., 1859, p. 27;—Pal. New York, IV, 1867, p. 271.—Nettelroth,
Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 135.—Hall
ke, Pal. New York, VIII, Pt. II, 1893, p. 124;—Thirteenth Ann. Rep.
te Geologist, 1895, p. 798.
ra Hall, Sixteenth Rep. N. Y. State Cab. Nat. Hist., 1863, p. 54.

acadiæ Hall and Clarke=Rhynchospira acadiæ.

mura Hall. Niagara (Sil.).
ra Hall, Pal. New York, II, 1852, p. 273, pl. 56, fig. 3.
camura Hall, Pal. New York, III, 1859, p. 212, pl. 28A, fig. 1.—Hall
ke, Pal. New York, VIII, Pt. II, 1893, p. 126, pl. 49, figs. 2–4.
camura Billings, Geol. Canada, 1863, p. 315, fig. 322.
t, New York.

stata Hall. Lower Helderberg (Dev.).
costata Hall, Pal. New York, III, 1859, p. 210, pl. 28A, 1859, fig. 4;—
V, 1867, p. 276, figs. 5, 6.—Hall and Clarke, Pal. New York, VIII,
5, pl. 49, figs. 19, 20.
and Schoharie counties, New York.

deweyi Hall=Parazyga deweyi.

disparilis Hall=Atrypina disparilis.

Digitized by Google

Trematospira dubia (Billings). Lower Helderberg (Dev.).

Retzia dubia Billings, Proc. Portland Soc. Nat. Hist., I, 1863, p. 113, pl. 3, fig. 10.

Trematospira dubia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 126, pl. 49, figs. 15, 16.

Loc. Square Lake, Maine.

Trematospira equistriata Hall and Clarke. Lower Helderberg (Dev.).

Trematospira equistriata Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 49, fig. 47.

Loc. Cumberland, Maryland.

Trematospira gibbosa Hall. Hamilton (Dev.).

Trematospira gibbosa Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 82;—Pal. New York, IV, 1867, p. 272, pl. 45, figs. 7–15.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 49, figs. 23–27.

Loc. Bellona, York, and Darien, New York.

Trematospira helena Nettelroth=Rhynchospira helena.

Trematospira hippolyte (Billings). Lower Helderberg (Dev.).

Retzia hippolyte Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 112, pl. 13, fig. 9.

Trematospira hippolyte Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 126, pl. 49, figs. 7, 8.

Loc. Square Lake, Maine.

Trematospira hirsuta Hall=Parazyga hirsuta.

Trematospira imbricata Hall=Atrypina imbricata.

Trematospira (?) liniuscula A. Winchell. Hamilton (Dev.).

Trematospira ? liniuscula A. Winchell, Rep. Lower Peninsula Michigan, 1866, p. 94.

Loc. Grand Traverse region, Michigan.

Trematospira matthewsoni McChesney=Atrypa marginalis.

Trematospira maria (Billings). Lower Helderberg (Dev.).

Retzia maria Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 112, pl. 3, fig. 8.

Trematospira maria Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 126, pl. 49, fig. 21.

Loc. Square Lake, Maine.

Trematospira multistriata Hall. Lower Helderberg (Dev.).

Spirifer multistriata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 59, figs. 1–6.

Trematospira multistriata Hall, Pal. New York, III, 1859, p. 209, pl. 24, fig. 3; pl. 28A, fig. 5;—Ibidem, IV, 1867, p. 276, figs. 1–3.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 126, fig. 110, pl. 49, figs. 9–14.

Retzia multistriata Billings, Geol. Canada, 1863, p. 958, fig. 458.

Loc. Schoharie, New York.

Trematospira nobilis Hall=Cyclorhina nobilis.

Trematospira perforata Hall. Lower Helderberg (Dev.).

Spirifer ? perforata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 60.

Trematospira perforata Hall, Pal. New York, III, 1859, p. 208, pl. 28A, fig. 3;—Ibidem, IV, 1867, p. 276.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 49, figs. 5, 6.

Loc. Albany and Schoharie counties and Hudson, New York.

Trematospira simplex Hall. Lower Helderberg (Dev.).

Trematospira simplex Hall, Pal. New York, III, 1859, p. 211, pl. 28A, fig. 2.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 49, figs. 17, 18.

Loc. Decatur County, Tennessee.

Digitized by Google

quadriplicata Miller=Rhynchotrema inæquivalve.

nnesseensis Hall and Clarke. Lower Helderberg (Dev.).
tennesseensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, s. 21–23.
ounty, Tennessee.

ayle partim) Hall and Clarke.
Genotype Terebratula guerangeri de Verneuil.
le (partim), Explic. Carte Géol de France, Atlas, 1875, pl. 13.—Hall ke, Pal. New York, VIII, Pt. II, 1893, pp. 272, 273, fig. 189;—Thir- ep. N. Y. State Geologist, 1895, p. 856.

ri (Œhlert). Oriskany (Dev.).
gaudryi Œhlert, Bull. Soc. Geol. France, 3d ser., V, 1877, p. 593, pl. —Bull. de la Soc. d'Etudes Scientif. d'Angers, separate 1883, p. 2, pl. 0–17.
dryi Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 273, fig. 6, figs. 6, 7.
Cumberland, Maryland.

ida Hall. Hamilton (Dev.).
a lepida Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. New York, IV, 1867, p. 276, pl. 45, figs. 1–6.
Miller, N. American Geol. Pal., 1889, p. 366.
pida Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 274, pl. 50, 0.
aigua Lake and Bellona, New York.

rgarida (Derby). Middle Devonian.
f) margarida Derby, Archivos do Museu Nacional Rio de Janeiro, p. 84, with figures in text.
rgarida Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 274.
Paraguay; Matto Grosso, Brazil.

tlandica (Billings). Lower Helderberg (Dev.).
portlandica Billings, Proc. Portland Soc. Nat. Hist., I, 1863, p. 115, 12.
rtlandica Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 273, s. 4, 5.
Lake, Maine.

rdiana (Rathbun). Middle Devonian.
iana (Hartt) Rathbun, Bull. Buffalo Soc. Nat. Sci., I, 1874, p. 245, s. 2–5, 8, 9, 11, 12, 14, 16.—Rathbun, Proc. Boston Soc. Nat. Hist., , p. 31.
diana Derby, Archivos do Museu Nacional do Rio de Janerio, IX, 8.
rdiana Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 274.
e of Para, Brazil.

Billings. Genotype T. grandis Billings.
Billings, Pal. Fossils, I, 1862, p. 166.—Dall, American Jour. Conch., p. 160;—Ibidem, VII, 1871, p. 79.—Davidson and King, Quart. Jour. c. London, XXX, 1874, p. 143.—Dall, Bull. U. S. National Mus., 8, 74.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pp. 33, 46. eventh Ann. Rep. N. Y. State Geologist, 1894, p. 236.
all, American Jour. Conch., VI, 1870, p. 160.

Digitized by Google

Trimerella acuminata Billings. Guelph (Sil.).

Trimerella acuminata Billings, Pal. Fossils, I, 1862, pp. 167, 168, fig. 152;—American Jour. Sci., 3d ser., I, 1871, p. 471;—Ann. Mag. Nat. Hist., 4th ser., VIII, 1871, p. 140.—Dall, American Jour. Conch., VII, 1871, p. 82.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 146, pl. 15, figs. 4–7; pl. 16, figs. 1, 2.—Nicholson, Pal. Prov. Ontario, 1875, p. 68, fig. 36.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4B, fig. 6.

Loc. Galt, New Hope, and Hespelar, Ontario; near Hillsboro, Ohio; Port Byron, Illinois; Gotland and Farö.

Trimerella billingsi Dall. Guelph (Sil.).

Trimerella billingsi Dall, American Jour. Conch., VII, 1871, p. 82, pl. 11, figs. 1–3.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 150, pl. 16, figs. 8, 9.

Loc. New Hope, Ontario, Canada.

Trimerella dalli Davidson and King. Guelph (Sil.).

Trimerella dalli Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 154, pl. 15, figs. 1–3.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4A, fig. 10.

Loc. Hespelar, Elora, and New Hope, Ontario, Canada.

Trimerella galtensis Hall=Rhinobolus galtensis.

Trimerella grandis Billings. Guelph (Sil.).

Trimerella grandis Billings, Pal. Fossils, I, 1862, pp. 166, 167, fig. 151.—Dall, American Jour. Conch., II, 1870, p. 160;—Ibidem, VII, 1871, p. 82.—Hall, Twenty-third Rep. N. Y. State Cab. Nat. Hist., 1873, pl. 13, figs. 11–16.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, pl. 13, figs. 2, 3.—Nicholson, Pal. Prov. Ontario, 1875, p. 67, fig. 37.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4A, figs. 1, 2; pl. 4B, figs. 2–5.

Loc. Galt, New Hope, and Elora, Hespelar, Ontario, Canada; near Hillsboro, Ohio; Wisconsin.

Trimerella minor Dall=Rhinobolus galtensis.

Trimerella ohioensis Meek. Niagara (Sil.).

Trimerella ohioensis Meek, American Jour. Sci., 3d ser., I, 1871, p. 305.—Dall, American Jour. Conch., VII, 1871, p. 83.—Davidson and King, Geol. Mag., IX, 1872.—Meek, Pal. Ohio, I, 1873, p. 183, pl. 16, fig. 1.—Davidson and King, Quart. Jour. Geol. Soc. London, XXX, 1874, p. 153, pl. 16, figs. 3–7; pl. 19, figs. 1–2.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, pl. 4A, figs. 3–9.

Loc. Genoa, Ottawa County, Ohio; Port Byron, Illinois; Ontario, Canada.

TRIPLECIA Hall. Genotype Atrypa extans Emmons.

Triplesia Hall, Pal. New York, III, 1859, p. 522;—Twelfth Rep. N. Y. State Cab Nat. Hist., 1859, p. 44.—Waagen, Palæontologica Indica, Ser. XIII, I, 1884, p. 576.

Triplecia Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 269.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 408.—Hall and Clarke, Eleventh Ann. Rep. N. Y. State Geologist, 1894, p. 289.

Dicraniscus Meek, American Jour. Sci., 3d ser., IV, 1872, p. 279.—Pal. Ohio, I, 1873, p. 576.

Triplecia cuspidata Hall. Trenton (Ord.).

Atrypa cuspidata Hall, Pal. New York, I, 1847, p. 138, pl. 33*, fig. 1, and p. 318.

Triplesia cuspidata Hall, Pal. New York, III, 1859, p. 522.—Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 270.

Loc. Lowville, Lewis County, New York.

Digitized by Google

(Emmons). Trenton (Ord.).
s Emmons, Geol. N. Y.; Rep. Second Dist., 1842, p. 395, fig. 6.—
New York, I, 1847, p. 137, pl. 33, fig. 1.
ns, Hall, Ibidem, III, 1859, p. 523, figs. 1–3.
ans Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 270,
gs. 1–7.
wn, Lowville, and Boonville, New York.

aensis Hall and Clarke. Niagara (Sil.).
arensis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 83,
.
waukee, Wisconsin.

s Hall. Trenton (Ord.).
is Hall, Pal. New York, I, 1847, p. 138, pl. 33, fig. 2.
leus Hall, Ibidem, III, 1859, p. 522.
leus, Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 270,
gs. 8, 9.
lle, New York.

Meek. Clinton (Sil.).
rtoni Meek, American Jour. Sci., 3d ser., IV, 1872, p. 280.
ni Meek, Pal. Ohio, I, 1873, p. 178, pl. 15, fig. 1.
oni, Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 270;
gs. 12–20.—Foerste, Geol. Ohio, VII, 1895, p. 585.
Ohio; Newson, Tennessee.

liata Whitfield. Calciferous (Ord.).
ata Whitfield, Bull. American Mus. Nat. Hist., II, 1889, p. 43, pl. 7,

iata, Hall and Clarke, Pal. New York, VIII, Pt. I, 1892, p. 271.
ntown, New York.

i Winchell and Schuchert. Lorraine (Ord.).
chi W. and S., Minnesota Geol. Survey, III, 1893, p.409, fig. 34.
and Spring Valley, Minnesota.

gua Hall=Camarella ambigua.
fera Walcott=Syntrophia calcifera.
esta Hall=Hyattella congesta.
alis Whitfield=Syntrophia lateralis.
ordialis Whitfield=Syntrophia primordialis.
lus Hall=Mimulus waldronensis.
ricostata Hall=Hyattella congesta.

US Hall. Genotype Strophomena carinata Conrad.
s Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p. 152 (unde-
Twelfth Rep. Ibidem, 1859, p. 31 (undefined); Twentieth Rep.—
867, pp. 165, 279;—Pal. New York, IV, 1867, p. 404.—Nettelroth,
Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 46.—Hall
ke, Pal. New York, VIII, Pt. II, 1893, p. 302;—Thirteenth Ann. Rep.
te Geologist, 1895, p. 870.

arinatus (Conrad). Marcellus and Hamilton (Dev.).
carinata Conrad, Third Ann. Rep. N. Y. Geol. Survey, 1839, p. 64.
costa (Hall) de Verneuil, Bull. Soc. Geol. France, 2d ser., IV, 1847,

s carinatus Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, p.
1, 2;—Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 31, figs.

Digitized by Google

Tropidoleptus carinatus (Conrad)—Continued.

1–4.—Rogers, Geol. Pennsylvania, II, Pt. II, 1858, p. 828, fig. 672.—H
New York, IV, 1867, p. 407, pl. 62, figs. 2, 3.—Meek and Worthen, Geol
Illinois, III, 1868, p. 427, pl. 13, fig. 2.—Rathbun, Bull. Buffalo Soc. N
I, 1874, p. 254, pl. 9, figs. 1, 9, 10, 26.—Derby, Bull. Mus. Comp. Zo
1876, p. 282.—Rathbun, Proc. Boston Soc. Nat. Hist., XX, 1879, p. 35.—
roth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889,
pl. 17, figs. 14, 15.—A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VI
p. 73, pl. 4, figs. 32–34.—Hall and Clarke, Pal. New York, VIII, Pt.
p. 304, figs. 227, 228, pl. 82, figs. 26–36.

Loc. New York; Falls of Ohio; Columbus, Ohio; Pennsylvania; Jackson
Illinois; Erere, Provin ce of Para, Brazil; Island of Coati, Lake
(Agassiz), and Rio Sicasica (Ulrich), Bolivia, South America; South
(Ulrich); France; Germany and England.

Tropidoleptus occidens Hall. Hamilton

Tropidoleptus occidens Hall, Thirteenth Rep. N. Y. State Cab. Nat. His
p. 91;—Pal. New York, IV, 1867, p. 408, pl. 61A, figs. 50–52.—Hall and
Pal. New York, VIII, Pt. II, 1895, pl. 82, figs. 37, 38.

Loc. Iowa City, Iowa.

UNCINULUS Bayle. Genotype Rhynchonella subwilsoni d'O

Uncinulus Bayle, Explic. de la Carte Géolog. France, IV, Atlas, 1878, pl.
17–20.—Waagen, Palæontologica Indica, Ser. XIII, I, 1883, p. 424.—
Fischer's Manuel de Conchyliologie, 1887, p. 1306.—Hall and Clarke,
York, VIII, Pt. II, 1893, p. 195;—Thirteenth Ann. Rep. N. Y. State G
1895, p. 828.

Uncinulus abruptus Hall. Lower Helderberg

Rhynchonella abrupta Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 185
fig. 1;—Pal. New York, III, 1859, p. 228, pl. 31, fig. 3.

Uncinulus abruptus Hall and Clarke, VIII, Pt. II, 1893, p. 199, pl. 58, fig

Loc. Albany and Schoharie counties, New York.

Uncinulus campbellanus (Hall). Lower Helderberg

Rhynchonella campbellana Hall, Tenth Rep. N. Y. State Cab. Nat. Hist.,
79;—Pal. New York, III, 1859, p. 239, pl. 43, fig. 2.

Loc. Albany County, New York.

Uncinulus mutabilis Hall. Lower Helderberg

Rhynchonella mutabilis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist.,
66, figs. 1–7;—Pal. New York, III, 1859, p. 225, pl. 29, fig. 4; pl. 30, figs.

Uncinulus mutabilis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893,
pl. 58, figs. 22–25.

Loc. Schoharie and Carlisle, New York.

Uncinulus nobilis Hall. Lower Helderberg

Rhynchonella nobilis Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 185
figs. 1–3.—Rogers, Geol. Pennsylvania, II, 1858, p. 825, fig. 645.—Ha
New York, III, 1859, p. 240, pl. 43, fig. 3.

Uncinulus nobilis Hall and Clarke, Pal. New York, VIII, Pt. II, 1895,
fig. 26.

Loc. Albany and Schoharie counties, New York; Pennsylvania.

Uncinulus nucleolatus Hall. Lower Helderberg

Rhynchonella nucleolata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist
p. 68;—Pal. New York, III, 1859, p. 227, pl. 31, figs. 1f, 2.—Billing
Portland Soc. Nat. Hist., 1863, p. 110, pl. 3, fig. 5.

Digitized by Google

latus Hall—Continued.
leolata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 199.
and Carlisle, New York; Square Lake, Maine; St. Blandine, New
, Canada.

idatus Hall. Lower Helderberg (Dev.).
pyramidata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857,
l. New York, III, 1859, p. 229, pl. 32, figs. 1, 2.
amidatus Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, pl. 58,
.
ounty, New York.

andi (Sowerby). Niagara (Sil.).
ricklandi Sowerby, Murchison's Sil. System, 1839, pl. 13, fig. 19.
tennesseensis Hall (non Roemer), Trans. Albany Institute, IV,
8;—Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., Doc. ed.,
3, figs. 34–40.—White, Second Ann. Rep. Indiana Bureau of Sta-
Geol., 1880, p. 496, pl. 3, figs. 2–4;—Tenth Rep. State Geol. Indiana,
3, pl. 3, figs. 2–4.
stricklandi Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist.,
879, p. 165, pl. 26, figs. 34–40;—Eleventh Rep. State Geol. Indiana,
3, pl. 26, figs. 34–40.—Nettelroth, Kentucky Fossil Shells, Mem.
Geol. Survey, 1889, p. 81, pl. 27, figs. 9–11; pl. 29, figs. 3–6.
cinulina) stricklandi Hall and Clarke, Pal. New York, VIII, Pt.
l. 58, figs. 38–40.
Waldron, Indiana; Louisville, Kentucky.

atus Hall. Lower Helderberg (Dev.).
vellicata Hall, Tenth Rep. N. Y. State Cab. Nat. Hist., 1857, pp.
. 2, 3;—Pal. New York, III, 1859, p. 230, pl. 33, fig. 1.
icata Hall and Clarke, Pal. New York, VIII, Pt. II, 1895, p. 199.
nd Schoharie counties, New York; Dalhousie, New Brunswick,

. Genotype V. pustulosa Hall.
Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p. 72, figs. 1, 2;—
York, IV, 1867, p. 410.—Hall and Clarke, Pal. New York, VIII, Pt.
138;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 804.

a Hall. Hamilton (Dev.).
ulosa Hall, Thirteenth Rep. N. Y. State Cab. Nat. Hist., 1860, p.
New York, IV, 1867, p. 410, pl. 62, fig. 1.—Rathbun, Bull. Buffalo
Sci., I, 1874, p. 255, pl. 9, figs. 2, 6–8, 11–13, 15, 20, 21, 27, 32.—Derby,
Comp. Zool., III, 1876, p. 282.—Rathbun, Proc. Boston Soc. Nat.
1879, p. 36.—A. Ulrich, N. Jahrb. f. Mineral., Beilageband, VIII,
3;—Ibidem, Beilageband, VIII, 1892, p. 71, pl. 4, figs. 26–29.—Hall
e, Pal. New York, VIII, Pt. II, 1893, pp. 139, 317, pl. 82, figs. 18–25.
ly and Tinkers Falls, New York; Monroe County, Pennsylvania;
vince of Para, and provinces Parana and Matto Grosso, Brazil;
Coati, Lake Titicaca, Tarabuco and Rio Sicasica, Bolivia; South

King. Genotype W. flavescens Lamarck.
ing, Mon Permian Fossils, Pal. Soc., 1850, p. 81.—Dall, American
ch., VI, 1870, p. 107.

atorcensis Aguilera. Jurassic.
atorcensis Aguilera, Bol. Com. Geologica de Mexico, I, 1895, p. 1,
3.
lamitos, San Luis, Potosi, Mexico.

Digitized by Google

Waldheimia compacta White and St. John=Cryptacanthia com
Waldheimia coutinhoana Derby=Harttina coutinhoana.
Waldheimia deweyi Hall=Parazyga deweyi.
Waldheimia formosa Hall=Rhynchospira formosa.
Waldheimia globosa Hall=Rhynchospira globosa.
Waldheimia imbricata Cooper=Terebratella? imbricata.

Waldheimia kennedyi Dall. Mi

Waldheimia kennedyi Dall, Proc. California Acad. Sci., 1874 (extract, p. 4
Loc. Cerros Island, Lower California.

Waldheimia rectirostra Hall=Rhynchospira rectirostris.
Whitfieldia Davidson=Meristina.

WHITFIELDELLA Hall and Clarke. Genotype Atrypa nitida

Whitfieldella Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 58;
teenth Ann. Rep. N. Y. State Geologist, 1895, p. 766.

Whitfieldella (?) billingsana (Meek and Worthen). Niagara

Centronella billingsiana Meek and Worthen, Geol. Survey Illinois, III,
352, figs. a, b, c; pl. 6, fig. 5.
Loc. Alexander County, Illinois.

Whitfieldella (?) bisulcata (Vanuxem). Lower Helderberg (

Atrypa bisulcata Vanuxem, Geol. N. Y.; Rep. Third Dist., 1842, p. 112.
Merista bisulcata Hall, Pal. New York, III, 1859, p. 253.
Loc. Litchfield, New York.

Whitfieldella cylindrica Hall. Clinton-Niagara

Atrypa cylindrica Hall, Pal. New York, II, 1852, p. 76, pl. 24, fig. 2.
Atrypa crassirostra Hall, Pal. New York, 1852, p. 269, pl. 55, fig. 4.
Merista cylindrica Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859,
Athyris cylindrica Billings, Geol. Canada, 1863, p. 317, fig. 333;—Geol. C
1863, p. 317, fig. 332.
Meristella (?Meristina) cylindrica Meek, Pal. Ohio, I, 1873, p. 180, pl. 15
Whitfieldella cylindrica Hall and Clarke, Pal. New York, VIII, Pt. II,
60, pl. 40, figs. 16–22.
Loc. Lockport, New York; Hillsboro, Ohio; Hamilton, Ontario; Anticos

Whitfieldella (?) harpalyce (Billings). Lower Helderberg (

Athyris harpalyce Billings, Proc. Portland Soc. Nat. Hist., 1863, p. 11
fig. 14.
Whitfieldella (?) harpalyce Hall and Clarke, Pal. New York, VIII, Pt. I
p. 60.
Loc. Square Lake, Maine.

Whitfieldella hyale (Billings). Guelph

Charionella ? hyale, Billings, Pal. Fossils, I, 1862, p. 166, fig. 150.
Whitfieldella hyale Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p
Charionella hyale Hall and Clarke, Ibidem, pl. 42, figs. 20, 21.
Loc. Galt and Elora, Ontario; Wisconsin (Whitfield).

Whitfieldella intermedia Hall. Clinton-Niagara

Atrypa intermedia Hall, Pal. New York, II, 1852, p. 77, pl. 24, figs. 3, 4, ?6.—
Geol. Pennsylvania, II, 1858, Pt. II, p. 823, fig. 634.
Merista intermedia Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859,
Athyris intermedia Nicholson and Hinde, Canadian Jour. Sci., XIV, 1874, p
Nicholson, Pal. Prov. Ontario, 1875, p. 61, fig. 32A.

Digitized by Google

rmedia Hall—Continued.
ntermedia Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p.
igs. 1, 2.
New York; Thorold, Ontario; Pennsylvania.

julia (Billings). Anticosti (Sil.).
illings, Pal. Fossils, I, 1862, p. 146, fig. 124.
Miller, N. American Geol. Pal., 1889, p. 354.

naviformis Hall. Clinton-Niagara (Sil.).
mis Hall, Geol. New York; Rep. Fourth Dist., 1843, p. 71, fig. 3;—
ork, II, 1852, p. 76, pl. 24, fig. 1.—Nicholson and Hinde, Canadian
n. ser., XVI, 1874, pp. 144, 157.
formis Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.
rmis Billings, Geol. Canada, 1863, p. 317, fig. 320.—Nicholson, Pal.
rio, 1875, p. 62, fig. 32E.
aviformis Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 60,
3.
, Sodus, etc., New York; Dundas, Ontario; Anticosti.

da Hall. Niagara (Sil.).
Hall, Geol. New York; Rep. Fourth Dist., Tables of Organic
3, 1843, fig. 5;—Pal. New York, II, 1852, p. 268, pl. 55, fig. 1.—
anadian Nat. Geol., I, 1856, p. 137, pl. 2, fig. 9.
Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.
Hall, Geol. Canada, 1863, p. 317, fig. 334.
la Hall, Trans. Albany Institute, IV, 1863, p. 226.
la Hall, Pal. New York, IV, 1867, p. 299;—Twenty-eighth Rep.
e Mus. Nat. Hist., 1879, p. 169, pl. 25, figs. 1-7;—Eleventh Rep.
. Indiana, 1882, p. 300, pl. 25, figs. 1-7.—Nettelroth, Kentucky
ls, Mem. Kentucky Geol. Survey, 1889, p. 102, pl. 33, figs. 10, 11.—
d Clarke, Mem. N. Y. State Mus., I, 1889, p. 70, pl. 7, figs. 6-10.
itida Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 59,
pl. 40, figs. 4-13.
etc., New York; Hamilton, Ontario; Waldron, Indiana; Louis-
ucky; Anticosti.

da oblata Hall. Niagara (Sil.).
var. oblata Hall, Pal. New York, II, 1852, p. 269, pl. 55, fig. 2.
var. oblata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859,
etc., New York.

nucleolata (Hall.) Coralline (Sil.).
ata Hall, Pal. New York, II, 1852, p. 328, pl. 74, fig. 10.
lata Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.
eolata Whitfield, Geol. Wisconsin, IV, 1882, p. 321, pl. 25, fig. 5.
, New York; near Milwaukee, Wisconsin.

ata Hall. Medina (Sil.).
Hall, Pal. New York, II, 1852, p. 9, pl. 4, figs. 4, 5.
Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 78.
?) oblata Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 60.
New York.

ata (Vanuxem). Waterlime (Sil.).
Vanuxem, Geol. New York; Rep. Third Dist., 1842, p. 112, fig. 5.—
m, Rep. Fourth Dist., 1843, p. 142, fig. 5.
Miller, American Pal. Fossils, 1877, p. 115.
na village, New York.

Digitized by Google

WILSONIA Kayser. Genotype Terebratula wilsoni Sowerby.

Wilsonia Kayser, Zeitschr. d. deutsch. geolog. Gesselsch., XXIII, 1871, p. 502.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 195;—Thirteenth Ann. Rep. N. Y. State Geologist, 1895, p. 827.

Uncinulina Bayle, Explic. de la Carte Géolog. France, IV, 1878, Atlas, pl. 13, figs. 13–16.

Obs. A subgenus of Camarotœchia.

Wilsonia kokomoensis (Miller). Waterlime (Sil.).

Rhynchonella kokomoensis Miller, Eighteenth Ann. Rep. Geol. Survey Indiana, 1894, p. 312, pl. 9, figs. 22–24.

Loc. Kokomo, Indiana.

Wilsonia saffordi Hall. Niagara and Lower Helderberg (Sil. and Dev.).

Rhynchonella saffordi Hall, Canadian Nat. Geol., V, 1860, p. 146.—Hall and Whitfield, Twenty-seventh Rep. N. Y. State Cab. Nat. Hist., 1875, pl. 9, figs. 27–29.—Dawson, Acadian Geol., 3d ed., 1878, p. 598.—Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 79, pl. 27, figs. 22–24; pl. 33, figs. 4–6.

Wilsonia saffordi Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 198, pl. 58, figs. 5–14.

Loc. In the Arisaig group of Nova Scotia; Perry County, Tennessee; Louisville, Kentucky.

Wilsonia saffordi depressa (Nettelroth). Niagara (Sil.).

Rhynchonella saffordi var. depressa Nettelroth, Kentucky Fossil Shells, Mem. Kentucky Geol. Survey, 1889, p. 80, pl. 33, fig. 1–3.

Loc. Louisville, Kentucky.

Wilsonia wilsoni (Sowerby). Niagara (Sil.).

Terebratula wilsoni Sowerby, Mineral Conchology, 1818, p. 118, fig. 3.

Rhynchonella wilsoni Roemer, Sil. Fauna d. West. Tennessee, 1860, p. 71, pl. 5, fig. 13.

Wilsonia wilsoni Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 198.

Loc. Europe; Decatur County, Tennessee; Louisville, Kentucky; Lake Temiscouata, New Brunswick.

YORKIA Walcott. Genotype Y. wanneri Walcott.

Yorkia Walcott, Proc. U. S. Nat. Mus., XIX, 1897, p. 714.

Yorkia wanneri Walcott. Lower Cambrian.

Yorkia wanneri Walcott, Proc. U. S. Nat. Mus., XIX, 1897, p. 715, pl. 60, figs. 1–1e.

Loc. Emigsville, Pennsylvania.

Yorkia (?) washingtonensis Walcott. Lower Cambrian.

Yorkia (?) washingtonensis Walcott, Proc. U. S. Nat. Mus., XIX, 1897, p. 715, pl. 60, fig. 3.

Loc. Salem, Washington County, New York.

ZYGOSPIRA Hall. Genotype Atrypa modesta Hall.

Stenocisma Hall (non Conrad), Pal. New York, I, 1847, p. 142.—Meek and Hayden, Pal. Upper Missouri, Smithsonian Cont. to Knowl., XIV, 1864, p. 16.

Zygospira Hall, Fifteenth Rep. N. Y. State Cab. Nat. Hist., 1862, p. 154, figs. 1, 2.—Billings, Canadian Nat. Geol., VII, 1862, p. 393.—Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., 1867, p. 267.—Meek, Geol. Survey, Illinois, III, 1868, p. 377.—Davidson, Suppl. British Silurian Brachiopoda, Pal. Soc., 1882, p. 122.—Winchell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 465.—Beecher and Schuchert, Biol. Soc. Washington, VIII, 1893, pp. 71–82.—Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 154.

Anazyga Davidson, Suppl. British Silurian Brachiopoda, Pal. Soc., 1882, p. 128.

Digitized by Google

l—Continued.

ell and Schuchert, Minnesota Geol. Survey, III, 1893, p. 471.
and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 151.
lina and Zygospira Hall and Clarke, Thirteenth Ann. Rep. N. Y.
gist, 1895, pp. 809, 810, 812.

a Sardeson=Z. nicoletti.

ostiensis Davidson=Catazyga erratica.

atiensis Meek. Lorraine (Ord.).

nnatiensis (James) Meek, Pal. Ohio, I, 1873, p. 126, pl. 11, fig. 5.—
cinnati Quart. Jour. Sci., II, 1875, p. 59.—Hall and Clarke, Pal.
VIII, Pt. II, 1895, pl. 54, figs. 13, 14.
, Ohio.

rica Ulrich. Lorraine (Ord.).

entrica Ulrich, Jour. Cincinnati Soc. Nat. Hist., II, 1879, p. 14,
).
, Ohio.

Hall. Trenton (Ord.).

Hall, Pal. New York, I, 1847, p. 140, pl. 33, fig. 4.
cta Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 157.
nty, New York; Ottawa, Canada.

(Hall). Trenton (Ord.).

Hall, Pal. New York, I, 1847, p. 141, pl. 33, fig. 6.
Hall, Twelfth Rep. N. Y. State Cab. Nat. Hist., 1859, p. 66.
ua Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 149, figs.
54, figs. 47, 48.
Watertown, and Martinsburg, New York.

ca Davidson=Catazyga erratica.

Hall=Catazyga headi.

kiensis James. Lorraine (Ord.).

esta var. kentuckiensis James, The Paleontologist, 1878, p. 7.
tuckiensis Nettelroth, Kentucky Fossil Shells, Mem. Kentucky
ey, 1889, p. 138, pl. 34, figs. 21–25.—Hall and Clarke, Pal. New
, Pt. II, 1895, pl. 54, figs. 11, 15, 16.
nd Jefferson counties, Kentucky.

a (Billings). Anticosti (Sil.).

nica Billings, Cat. Sil. Foss. Anticosti, 1866, p. 44.
ca Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 157.
of the Anticosti group, Anticosti.

ima Hall. Niagara (Sil.).

ima Hall, Descrip. n. sp. Foss. Waldron, Indiana, 1879, p. 14;—
Rep. Indiana State Geologist, 1882, p. 305, pl. 27, fig. 7;—Trans.
titute, X, 1883, p. 70.
Indiana.

a Hall. Utica and Lorraine (Ord.).

a (Say) Hall, Pal. New York, I, 1847, p. 141, pl. 15, fig. 15;—Thir-
. N. Y. State Cab. Nat. Hist., 1860, p. 69.
esta Hall, Fifteenth Rep. N. Y. State Cab. Nat. Hist., 1862, p.
ntieth Rep. Ibidem, 1867, p. 267, figs. 1, 2.—Meek, Pal. Ohio, I, 1873,
11, fig. 4.—Miller, Cincinnati Quart. Jour. Sci., II, 1875, p. 58.—
Suppl. British Sil. Brachiopoda, Pal. Soc., 1882, p. 122.—Winchell

Digitized by Google

Zygospira modesta Hall—Continued.

and Schuchert, Minnesota Geol. Survey, III, 1893, p. 467, pl. 34, figs.
Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p. 155, figs. 146
54, figs. 7-10, 12.—Keyes, Geol. Survey Missouri, V, 1895, p. 98.

Rhynchonella? modesta Billings, Geol. Canada, 1863, p. 211, fig. 211.

Loc. Cincinnati, Ohio; Turin, etc., New York; Lattners, Iowa; Spring
Minnesota; Wisconsin; St. Louis County, Missouri; Ottawa, Canad

Zygospira nicoletti Winchell and Schuchert. Trenton

Hallina nicoletti W. and S., American Geol., IX, April 1, 1892, p. 293;—M
Geol. Survey, III, 1893, p. 474, pl. 34, figs. 59–62.

Zygospira aquila Sardeson, Bull. Minnesota Geol. Survey, III, April 9,
335, pl. 4, figs. 15–18.

Zygospira nicolleti Beecher and Schuchert, Biol. Soc. Washington, VII
1893, p. 71, pl. 10, fig. 23; pl. 11, figs. 11, 12.

Loc. Minneapolis, Rochester, and Fountain, Minnesota; Decorah, Iowa
Wisconsin; Auburn, Missouri.

Zygospira paupera Billings. Anticost

Zygospira paupera Billings, Cat. Sil. Fossils Anticosti, 1866, p. 46.—
Clarke, Pal. New York, VIII, Pt. II, 1893, p. 157.

Loc. Division 3 of Anticosti group, Anticosti.

Zygospira putilla Hall and Clarke. ? Lorraine

Zygospira putilla Hall and Clarke, Pal. New York, VIII, Pt. II, 1893, p.
150, p. 365, pl. 54, figs. 35–37; pl. 83, figs. 29, 30.

Loc. Pike County, Missouri.

Zygospira recurvirostris (Hall). Trenton

Atrypa recurvirostris Hall, Pal. New York, I, 1847, p. 140, pl. 33, fig. 5.

Rhynchonella recurvirostris Billings, Geol. Canada, 1863, p. 168, fig. 152.

Anazyga recurvirostra Davidson, Suppl. British Sil. Brachiopoda, P
1892, p. 129.

Zygospira recurvirostra Winchell and Schuchert, Minnesota Geol. Sur
1893, p. 466, pl. 34, figs. 38–41.—Beecher and Schuchert, Biol. Soc. Was
VIII, 1893, p. 71, pl. 10, figs. 7–21; pl. 11, figs. 1–10.—Hall and Clarke,
York, VIII, Pt. II, 1895, pl. 54, figs. 1–6.—Whiteaves, Pal. Foss., III,
1897, p. 180.

Loc. New York; Kentucky; Iowa; Minnesota; Wisconsin; Ottawa,
Lake Winnipeg, Manitoba. According to Billings it occurs also in
raine group of Anticosti.

Zygospira saffordi Winchell and Schuchert. Trenton

Hallina saffordi W. and S., American Geol., IX, 1892, p. 292;—Minneso
Survey, III, 1893, p. 473, pl. 34, figs. 55–58.—Hall and Clarke, Pal. Ne
VIII, Pt. II, 1895, pl. 83, figs. 36–38.

Zygospira saffordi Beecher and Schuchert, Biol. Soc. Washington, VIII,
71, pl. 10, fig. 22; pl. 11, figs. 13, 13a.—Hall and Clarke, Pal. New Yo
Pt. II, 1893, p. 151, figs. 139–141.

Loc. Lebanon, Tennessee; Highbridge, Kentucky.

Zygospira (?) subconcava Meek and Worthen. Lower Helderberg

Zygospira subconcava Meek and Worthen, Geol. Survey Illinois, III, 186
pl. 7, fig. 1.

Loc. Perry County, Missouri.

Zygospira uphami W. and S.=Catazyga uphami.

Digitized by Google

PARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

LOGICAL SURVEY

No. 88

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

THE CRETACEOUS FORAMINIFERA OF NEW JERSEY

BY

RUFUS MATHER BAGG, JR

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Letter of transmittal	7
Preface	9
Introduction	11
Classification of strata	16
Bibliography	17
Descriptive terms	25
Description of genera and species	27
Geological distribution	69
Index	87

ILLUSTRATIONS.

		Page.
PLATE I.	Diagrams illustrating descriptive terms	76
II.	Haplophragmium concavum Bagg Verneuilina triquetra (Von Münster) Vitrewebbina sollasi Chapman Vitrewebbina lævis (Sollas) Bolivina punctata d'Orb Frondicularia alata d'Orb (bottom form fig. 4b) Frondicularia ovata Roemer (bottom form figs. 4a, 5b)	78
III.	Nodosaria zippei Reuss Nodosaria williamsi Bagg Frondicularia major Bornemann Frondicularia clarki Bagg Frondicularia archiaciana d'Orb, var. strigillata Bagg Frondicularia reticulata Reuss Frondicularia angusta Nilsson, var. dimidia Bagg	80
IV.	Flabellina sagittaria (Lea) Frondicularia ovata Roemer Vaginulina strigillata Reuss Vaginulina legumen (Linne) Cristellaria italica (Defrance)	82
V.	Cristellaria projecta Bagg Cristellaria cretacea Bagg Pulvinulina reticulata Reuss, var. carinata Bagg	84
VI.	Cristellaria cultrata (Montfort) Polymorphina communis d'Orb Polymorphina emersoni Bagg Anomalina grosserugosa (Gumbel) Anomalina ammonoides (Reuss)	86

Digitized by Google

Digitized by Google

LETTER OF TRANSMITTAL.

UNITED STATES GEOLOGICAL SURVEY,
Baltimore, Md., March 1, 1897.

SIR: I have the honor to submit herewith the manuscript of a report upon the Cretaceous Foraminifera of New Jersey, which has been prepared by Dr. R. M. Bagg as a member of my division, and I would suggest that it be published as a bulletin of the Survey.

Very respectfully,

WM. BULLOCK CLARK,
Geologist.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

Digitized by Google

Digitized by Google

PREFACE.

The Foraminifera described in this bulletin were collected by the author from the Greensand series of the Upper Cretaceous of New Jersey, and include representatives from the Matawan, Monmouth, Rancocas, and Manasquan formations. They were determined, described, and presented as a thesis at the Johns Hopkins University for the degree of doctor of philosophy in the year 1895, and the types are deposited in the geological museum of that university, at Baltimore, Maryland. Some additional results of later study have yielded a number of interesting forms which are here described for the first time.

The author wishes to express his gratitude to Prof. W. B. Clark, who has kindly assisted in the work, and under whose direction the investigation has been carried on.

Acknowledgments are due the following persons who have furnished material for comparative study: Dr. G. Brown Goode, of Washington; Prof. Charles W. Johnson, of the Wagner Free Institute of Science, Philadelphia; Mr. T. W. Stanton and Dr. W. H. Dall, of Washington; Prof. Alonzo Linn, of Washington and Jefferson College, Pennsylvania; and Mr. Lewis Woolman, of Philadelphia.

The writer is also under great obligation to Mr. Frederick Chapman and Charles D. Sherborn, of London, England, for their kind assistance in determining doubtful forms, and for their approval of the new species herein described.

Digitized by Google

Digitized by Google

THE CRETACEOUS FORAMINIFERA OF NEW JERSEY.

By R. M. Bagg, Jr.

INTRODUCTION.

The fossil Foraminifera of America have never received much attention, although some of the most distinguished European paleontologists have been at work upon this group for many years, and have published numerous monographs and special reports upon it. Within the last few years, however, several short papers have appeared upon the Cretaceous Foraminifera of Canada, Minnesota, New Jersey, and Alabama.

The first report upon the Cretaceous Foraminifera of Canada was published by Dr. G. M. Dawson,[1] in the Canadian Naturalist for 1874. Four species of Foraminifera are described and figured in this report, namely: *Discorbina globularis*, *Planorbulina ariminensis*, *Textularia globulosa*, and *Textularia pygmæa*. These forms were discovered in the Cretaceous rocks of Pembina, Manitoba, which bear some resemblance to the "chalk" of Nebraska.

J. B. Tyrrell[2] has recognized in the Niobrara limestone of Manitoba some 25 different species of Foraminifera, a tabulated list of which appeared in the Transactions of the Royal Society of Canada and in the Annual Report of the Geological Survey of Canada[3] for 1890 and 1891.

Sixteen species of Foraminifera from the Cretaceous bowlder clays of central Minnesota were described and figured by Woodward and Thomas[4] in 1885. This report was reprinted, with additions of fossils from Nebraska and Illinois, in the Final Report of the Geological Survey of Minnesota.[5]

[1] Note on the occurrence of Foraminifera, coccoliths, and rhabdoliths in the Cretaceous rocks of Manitoba: Canadian Naturalist, new series, Vol. VII, 1874, pp. 252–257.

[2] Foraminifera and Radiolaria from the Cretaceous of Manitoba: Trans. Royal Soc. Canada, Vol. VIII, 1890, sec. 4, pp. 111–115.

[3] Geol. Surv. Canada, Rept. 1890–91, Vol. V, pt. 1, p. 211.

[4] On the Foraminifera of the bowlder clay taken from a well shaft 22 feet deep, Meeker County, central Minnesota: Geol. Nat. Hist. Surv. Minnesota, Thirteenth Ann. Rept., for 1884, pp. 164–177, Pls. I–III.

[5] Final Rept. Geol. Nat. Hist. Surv. Minnesota, Vol. III, 1893, pp. 23–54, Pls. C–E.

Digitized by Google

The Journal of the New York Microscopical Society for April, 1890,[1] contains a short article on the Cretaceous Foraminifera of New Jersey, by Dr. Anthony Woodward. This paper is entitled Synopsis of the Cretaceous Foraminifera of New Jersey, and contains only a review of previous investigations. A second part, however, appeared in the same journal for 1894,[2] in which Dr. Woodward describes 58 different species of Foraminifera from the New Jersey marl beds.

Still more recently a tabulated list of the Cretaceous and Tertiary Foraminifera of Alabama has been published in a special report of the Geological Survey of Alabama.[3]

The present memoir is a more thorough account than has previously been given of the Cretaceous Foraminifera from the marl beds of New Jersey. It was presented as a thesis at the Johns Hopkins University in May, 1895, but has been somewhat revised and enlarged, and contains descriptions of a number of species from the upper beds of the Matawan formation, which are here given for the first time. The latter were collected by the author during the last summer, while he was engaged in geological mapping in southern New Jersey. The specimens were obtained at Marshalltown, Salem County, New Jersey, in a very fossiliferous bed of sandy marl, which has been dug as a fertilizer.

A large amount of material has been collected and examined in the preparation of this report, from the following localities:

Monmouth formation (Navesink division, or lower marl bed): Atlantic Highlands, Freehold, and Cream Ridge.

Rancocas formation (middle marl bed): Blue Ball, New Egypt, Vincentown, Swedesboro, Timber Creek, and Harrisonville; also from a well boring at Quinton.

Manasquan formation (upper marl bed, lower part): Vincentown.

It was hoped that a careful study of the Foraminifera found in these various marl beds might not only result in the addition of many new species to our American Cretaceous, but might also serve as a means of identification of these strata. Such has been found to be the case, although the fact that certain species are present in several or all the beds has been established, while many of them have continued through deposits of later age and are found in existing oceans.[4]

The writer believes that the localities from which the fossils were collected for study are as typical as any which might have been chosen, although further investigation in many new localities can hardly fail to yield additional results.

The excellent state of preservation and the large size of many of the species are most striking and bear witness to the favorable conditions for their existence in the late Cretaceous sea.

---

[1] Cretaceous Foraminifera of New Jersey, Part I: Jour. N. Y. Micros. Soc., Vol. VI, No. 2, April, 1890, pp. 45–55.

[2] Ibid., Part 2, Vol. X, No. 4, Oct., 1894, pp. 91–141.

[3] Geol. Surv. Alabama, Rept. Geology Coastal Plain, 1894, pp. 93, 249, 285, 286, 288, 289.

[4] For geological distribution of these forms see tabular review, pp. 69–71.

Digitized by Google

Specimens of three types have been analyzed, two of calcareous and one of arenaceous character, in order to determine the amount of silica which is present. The analyses were made by Mr. W. F. Hillebrand, and the results are as follows:

No. 1. *Verneuilina triquetra* (von Münster).

	Per cent.
Silica	38.3
Additional insoluble matter	3.07
Total insoluble matter	41.37

This is an arenaceous-siliceous type, and the large amount of silica present is in the form of polished sand grains, with scattered grains of glauconite, which have been firmly cemented together.

No. 2. *Flabellina sagittaria* (Lea).

	Per cent.
Silica	1.2
Additional insoluble matter	0.55
Total insoluble matter	1.75

The base of the additional insoluble matter consisted of alumina and magnesia, together with a trace of iron and probably alkalies.

No. 3. *Nodosaria consobrina*, var. *emaciata* (Reuss).

	Per cent.
Silica	1.8

It is an interesting fact bearing on the origin of greensand that the writer has frequently found shells of Foraminifera filled with glauconite. This has been especially noticeable in *Polymorphina communis*, which in some cases, where the shell is broken away, shows the interior filled with light-green glauconite still bearing upon its outer surface the smooth impress of the shell.

Many Cristellariæ are partially filled with a light-brown clay suggesting the early stage in the formation of the glauconite grain. Upon a few grains of glauconite I have found clinging to the central portion remnants of the original shell, while the glauconite still shows an internal cast of the shell.

It is perhaps rather remarkable that among so many grains of glauconite so few perfect casts of Foraminifera are found and so small a number of intermediate stages, but it must be remembered that the shell wall of the forms is always thin and easily destroyed through solution in the percolating waters in such porous beds. Even among the Lamellibranchiata and Gasteropoda casts of the shells are much more abundant than well-preserved shells, except the heavier, ponderous shells of *Exogyra costata* and *Gryphæa vesicularis*. From the size of the glauconite grains and the peculiarity of their shape it is probable that the glauconite has grown by accretion around an original nucleus, so that the outline of the delicate shells is only exceptionally preserved.

Transverse sections of the glauconite grains show a difference in color and texture between the internal and external parts, the inner

Digitized by Google

portion being of a light olive-green and softer than the dark-green irregular border.

Several analyses of New Jersey glauconite have been made from carefully selected grains; one made by T. Sterry Hunt is as follows:[1]

Analysis of selected grains of New Jersey glauconite.

SiO_2	50.70	K_2O	5.80
FeO	22.50	Na_2O	0.75
MgO	2.16	H_2O	8.95
CaO	1.11		100.00
Al_2O_3	8.03		

It is not the object of this paper to enter into any discussion of the much-disputed problem of the origin of greensand. This subject has been discussed by numerous writers, especially of late by Murray and Renard[2] in their report upon the deep-sea deposits obtained by the *Challenger* Expedition. A statement of the results brought out by this investigation, with a short review of former theories, has been published by Prof. W. B. Clark[3] in his discussion of the origin of the greensand of New Jersey. That both organic and inorganic materials must be present for the formation of greensand has been established, but just what proportion of each is necessary is not so readily determined. The inorganic material occurring in the New Jersey marl beds is chiefly quartz and mica, and is supposed to have been derived from the crystalline rocks of Pennsylvania and northern New Jersey.

The greensands differ in the size of the sand grains, in the amount of rounding, and in the proportion of sand to glauconite. In the Manasquan formation (lower part of upper marl bed) there is proportionately more glauconite than in any of the other beds, while the quartz grains are more rounded than in the lower beds of the Monmouth formation, though perhaps less so in the upper or Redbank series. So large an amount of quartz sand is present in this latter bed that glauconite holds only a secondary place. For this reason no Foraminifera are known from the Redbank sands, although it is probable that the upper and lower portions of the bed will furnish some when more thoroughly examined.

The Navesink marls contain more Foraminifera than the Manasquan beds, and in a somewhat better state of preservation, but it is in the limestone layer of the Rancocas formation (middle marl bed) that the greatest abundance of forms is found. This deposit, frequently consolidated, is made up of great quantities of bryozoan shells and vast numbers of perfectly preserved Foraminifera. Seventy-nine species have been determined from this horizon alone. Four species are present in all four marl beds, namely: *Nodosaria obliqua* (Linné), *Nodosaria polygona* Reuss, *Nodosaria zippei* Reuss, and *Truncatulina lobatula* (Walker and Jacob).

[1] Mineral Physiology and Physiography, 1886, p. 198.

[2] Reports *Challenger* Expedition; Deep-sea deposits, 1892.

[3] A preliminary report on the Cretaceous and Tertiary formations of New Jersey: Report of the State Geologist of New Jersey for 1892, pp. 167–246.

Digitized by Google

HISTORICAL SUMMARY.

The value of the greensand marls for fertilizing purposes has been known in New Jersey for more than a century. In 1768 a laborer, while digging a ditch in a meadow near Marlboro, threw out a substance which was pronounced to be *marl*. Some of this marl was spread upon the land with good results, but no particular attention seems to have been paid to the discovery until the year 1811, when its value began to be appreciated.

The discovery of fossils in the marl beds was made soon after, and in 1820 some of these fossils were described by Say,[1] and others by Morton[2] in 1829.

The first mention of Foraminifera was made by Isaac Lea[3] in 1833, in his Contributions to Geology, when he described *Flabellina sagittaria* as *Palmula sagittaria* from the Cretaceous deposit of Timber Creek, New Jersey, in which he considered the form a new genus of the family Spherulacea of Blainville. The genus Palmula Mr. Lea considered as intermediate between the genus Saracenaria of Defrance and the genus Textularia of the same author. This same species was described by Dr. S. G. Morton[4] in 1842 as *Planularia cuneata*.

In the American Journal of Science for 1841[5] Prof. J. W. Bailey gives a brief note on the discovery of fossil Foraminifera in New Jersey, and states that "a large portion of the calcareous rock defined by Prof. H. D. Rogers[6] as the third formation of the upper secondary is made up of great quantities of microscopic shells belonging to the Foraminifera."

Sir Charles Lyell,[7] on his visit to America in the year 1841, noticed the occurrence of Foraminifera in the Cretaceous marl beds of New Jersey, and mentioned three very common types, Cristellaria, Rotalia (Rotalina), and Nodosaria.

In his Origin of Greensand, and its Formation in the Oceans of the Present Epoch,[8] Prof. J. W. Bailey refers to the deposits at Mullica Hill and Mount Holly, New Jersey, as being very rich in greensand casts of Polythalamia.

Mr. W. M. Gabb, in Descriptions of New Species of American Tertiary and Cretaceous Fossils,[9] describes one of the Nodosariæ from Mullica Hill as a new species under the name *Dentalina pulchra*, but which is known to be *Nodosaria zippei* Reuss.

The first report of any importance upon the determination of these

---

[1] Am. Jour. Sci., 1st series, Vol. II, 1820, pp. 34–45.
[2] Jour. Acad. Nat. Sci. Philadelphia, Vol. VI, 1829, pp. 120–129.
[3] Contributions to Geology, 1833, pp. 219–220, Pl. VI, fig. 228.
[4] Jour. Acad. Nat. Sci. Philadelphia, Vol. VIII, 1842, pp. 214–215, Pl. XI, fig. 5.
[5] Am. Jour. Sci., 1st series, Vol. XLI, 1841, pp. 213–214.
[6] Report of the Geol. Surv. of the State of New Jersey, 1836, pp. 10–13.
[7] Quart. Jour. Geol. Soc. London, Vol. I, 1845, pp. 56, 57, and 64. See, also, Travels in North America, I, 1845, p. 64.
[8] Proc. Boston Soc. Nat. Hist., Vol. V, 1856, pp. 365, 366.
[9] Jour. Acad. Nat. Sci. Philadelphia, new series, Vol. IV, 1860, pp. 375–406, Pl. LXIX.

Digitized by Google

microscopic organisms was published in 1861 by Prof. A. E. Reuss,[1] one of the most distinguished of European paleontologists. In this article, entitled Die Foraminiferen der senonischen Gründsandes von New Jersey, Professor Reuss described some 28 different species of Foraminifera, but mentioned neither the horizon nor the localities from which they were obtained. While a few of these forms were figured in this report, the majority are given in other works.

Hermann von Credner[2] in 1870 published an article entitled Die Kreide von New Jersey, which contained a general review of the Cretaceous of New Jersey. In this report two Foraminifera from the Bryozoa bed at Brownville, *Flabellina cordata* Reuss and *Nodosaria sulcata* Nilsson, are described.

Subsequent to Professor Credner's report in 1870 no work was done upon the Foraminifera of New Jersey until the year 1894, when Dr. Woodward[3] published the second part of his Cretaceous Foraminifera of New Jersey. In this report some 58 species of Foraminifera from Timber Creek, Mullica Hill, New Egypt, and Bruere's pits, on Crosswicks Creek, are described but not figured.

The material investigated at the geological laboratory of the Johns Hopkins University has furnished nearly twice as many species as previously reported, and six of these are considered to be new. A preliminary report of this investigation, containing a description of the new forms and a tabulated list of other species identified, was published by the author[4] in 1895.

The Foraminifera described in this bulletin are deposited in the geological museum at the Johns Hopkins University, Baltimore, Maryland.

CLASSIFICATION OF STRATA.

The classification of the marl beds adopted in this report is one employed by Prof. W. B. Clark in his report, lately published, upon the Upper Cretaceous formations of New Jersey, Delaware, and Maryland,[5] viz:

Age.	*Formation.*		
Eocene	Shark River		Upper marl bed.
Upper Cretaceous	Manasquan		
	Rancocas	Vincentown lime sands	Middle marl bed.
		Sewell marls	
	Monmouth	Redbank sands	Red sand and lower marl bed.
		Navesink marls	
		Mount Laurel sands	
	Matawan	Hazlet sands	Clay marls.
		Crosswicks clays	

[1] Sitz. Akad. Wiss. Wien, Vol. XLIV, pt. i, 1861, pp. 334–342, plates.
[2] Zeitsch. d. D. geol. Gesell., 1870, Vol. XXII, pp. 191–251.
[3] Jour. N. Y. Micros. Soc., Vol. X, No. 4, Oct., 1894, pp. 91–141.
[4] Johns Hopkins Univ. Circulars, No. 121, Oct., 1895.
[5] Bull. Geol. Soc. America, vol. 8, pp. 315–358, pls. 40–50.

Digitized by Google

BIBLIOGRAPHY.

Within the last ten years several bibliographies of the Foraminifera have appeared, which have been of invaluable assistance in the preparation of this report. The best bibliography which has yet been published is that of Prof. Charles D. Sherborn, entitled A Bibliography of the Foraminifera, Recent and Fossil, from 1565 to 1888. (London, 1888.) This excellent catalogue is based upon the bibliography given by Prof. H. B. Brady in the *Challenger* report, but has been greatly enlarged and revised.

Another bibliography, less exhaustive, compiled by Dr. Anthony Woodward, was published in the Fourteenth Annual Report of the Geological and Natural History Survey of Minnesota for the year 1885.

There has lately been published in the Smithsonian Miscellaneous Collections An Index to the Genera and Species of the Foraminifera, by Charles D. Sherborn. This exhaustive work, invaluable to all students of Foraminifera, is in two parts, and forms a portion of Volume XXXVII of the Smithsonian reports. The first part was published in November, 1893, and included all names from A to N, while the second portion, published in 1896, completes the alphabetic list of forms from N to Z. The most distinguished specialists in the Foraminifera have been consulted by Professor Sherborn in the preparation of this laborious work, and too much praise can not be given the author for the completeness and accuracy of its contents.

The following is a list of works consulted in the preparation of this report. No attempt is made to give a complete bibliography; only those publications which have been most useful are included:

AGASSIZ, Alexander. On the Explorations in the Vicinity of the Tortugas during March and April, 1881 (Pelagic Fauna of the Gulf Stream).

Bull. Mus. Comp. Zool., Harvard, Vol. IX, 1881, pp. 145–149.

—— A Contribution to American Thalassography.

Bull. Mus. Comp. Zool., Harvard, Vols. XIV, XV, 1888, and 2 vols., 8°, London, 1888.

ALTH, Alojzy. Geognostisch-paläontologische Beschreibung der nächsten Umgebung von Lemberg.

Haidinger's Naturw. Abhandl., Vol. III, Abth. 2, 1850, pp. 171–284, Pls. IX–XIII (pp. 262–271, Pl. XIII).

ANDREAE, A. Ein Beitrag zur Kenntniss des Elsässer Tertiärs..

Abhandl. Geol. Special-Karte Elsass-Lothringen, Vol. II, Heft 3, 1884, 331 pp., Pls. I–XII.

ANSTED, David Thomas. The Deposits of the North Atlantic in Deep Water, and their Relation to the White Chalk of the Cretaceous Period.

Pop. Science Review, Vol. IX, 1870, pp. 24–33, Pl. LV.

Digitized by Google

BAILEY, Jacob Whitman. Note on the Discovery of "Fossil Foraminifera in the Green Sand of New Jersey."

Am. Jour. Sci., ser. 1, Vol. XLI, 1841, pp. 213–214.

—— American Polythalamia from the Upper Mississippi, and also from the Cretaceous Formation of the Upper Missouri.

Am. Jour. Sci., ser. 1, Vol. XLI, 1841, pp. 400–401; 4 woodcuts.

—— On Fossil Foraminifera in the Calcareous Marl from the Cretaceous Formation on the Upper Missouri.

Proc. Acad. Nat. Sci., Philadelphia, Vol. I, 1843, p. 75.

—— Microscopical Examination of Soundings made by the U. S. Coast Survey off the Atlantic Coast of the United States.

Smithsonian Contributions, Vol. II, 1851, art. 3, pp. 1–15; plate. Reprinted in Rept. U. S. Coast Survey for 1855 (1856), p. 360.

—— Silicified Polythalamia in Florida.

Am. Jour. Sci., ser. 2, Vol. II, 1851, p. 86.

—— On the Origin of Greensand and its Formation in the Oceans of the Present Epoch.

Proc. Boston Soc. Nat. Hist. Vol. V, 1856, pp. 364–368. Am. Jour. Sci., ser. 2, Vol. XXII, 1856, pp. 280–284. Quart. Jour. Microsc. Science, Vol. V, 1857, pp. 83–87.

BEISSEL, Ignaz. Die Foraminiferen der Aachener Kreide.

Abhandl. geol. Specialkarte von Preussen und d. Thüringischen Staaten, Neue Folge, Heft 3, 1891, Pls. I–XVI.

BERTHELIN, Georges. Mémoire sur les foraminifères fossiles de l'étage Albien de Moncley (Doubs).

Mém. Soc. Géol. France, ser. 3, Vol. I, No. 5, 1880, pp. 1–84, Pls. XXIV–XXVII.

BORNEMANN, Johann Georg. Die microscopische Fauna des Septarienthones von Hermsdorf bei Berlin.

Zeitsch. d. D. geol. Gesell, Vol. VII, 1855, pp. 307–371, Pls. XII–XXI.

BRADY, Henry Bowman. Report on the Foraminifera dredged by H. M. S. *Challenger* during the years 1873–1876.

Reports of the Scientific Results of the Voyage of H. M. S. *Challenger*, Vol. IX, (Zoology), 1884, pp. 814, figures and volume of 115 plates.

—— PARKER, W. K., and JONES, T. R. A Monograph on the Genus Polymorphina.

Trans. Linn. Soc., London, Vol. XXVII, 1870, pp. 197–253, Pls. XXXIX–XLII, and figures in text.

BRONN, Heinrich Georg. Lethaea Geognostica, Ed. 3, 1851–1856.

Vol. I, Theil I, pp. 106–109; Vol. II, Theil V, pp. 81–96, Pls. XXIX, XXXIII, XLII; Vol. III, Theil VI, pp. 197–255, Pls. XXXV^2, XXXV^3, XLII.

—— Die Klassen und Ordnungen des Thier-Reichs, wissenschaftlich dargestellt in Wort und Bild.

Band I, Amorphozoen, 1859, pp. 45–81, Pls. V–VII.

Digitized by Google

BURROWS, H. W., SHERBORN, C. D., and BAILEY, George. The Foraminifera of the Red Chalk.

Jour. Royal Microsc. Soc., London, ser. 2, Vol. VIII, 1888, pp. 383–385.

—— —— —— The Foraminifera of the Red Chalk of Yorkshire, Norfolk, and Lincolnshire.

Jour. Royal Microsc. Soc., London, 1890, pp. 549–564, Pls. VIII–XI.

CARPENTER, William Benjamin. On the Systematic Arrangement of the Foraminifera.

Nat. Hist. Review, Vol. I, 1861, pp. 456–472.

—— PARKER, W. K., and JONES, T. R. Introduction to the Study of the Foraminifera.

Ray Society, London, 1862, 319 pp., 22 plates.

CHAPMAN, Frederick. Some new forms of Hyaline Foraminifera from the Gault.

Geol. Mag., Decade III, n. s., Vol. IX, 1892, no. 11, pp. 52–54, Pl. II.

—— The Foraminifera of the Gault of Folkstone.

Jour. Royal Micros. Soc. London, 1891, Part I, pp. 565–575, Pl. IX; Ibid, 1892, Part II, pp. 319–330, Pls. V, VI; Ibid, 1892, Part III, pp. 749–758, Pls. XI, XII; Ibid, 1893, Part IV, pp. 579–595, Pls. VIII–IX.

—— Microzoa from the Phosphatic Chalk of Taplow.

Quart. Jour. Geol. Soc. London, 1892, pp. 514–518, Pl. XV.

—— On a Phosphatic Chalk with *Holaster planus* at Lewes. (By A. Strahan.) Appendix by F. Chapman. The Foraminifera and Ostracoda.

Quart. Jour. Geol. Soc. London, Vol. LII, 1896, pp. 470–472.

—— On the Rhizopodal Genera Webbina and Vitrewebbina.

Ann. and Mag. Nat. Hist., ser. 6, Vol. XVIII, 1896, pp. 326–333; figures.

CONRAD, Timothy Abbot. Description of New Species of Organic Remains from the Upper Eocene Limestone of Tampa Bay.

Am. Jour. Sci., ser. 2, Vol. II, 1846, pp. 399–400.

—— Check List of the Invertebrate Fossils of North America. Eocene and Oligocene.

Smithsonian Misc. Coll., Vol. VII, 1866, No. 200, pp. 1–34.

CORNUEL, J. Description de nouveaux fossiles microscopiques du terrain crétacé inférieur du département de la Haute-Marne.

Mém. Soc. Géol. France, ser. 2, Vol. III, 1848, pp. 241–263, Pls. III, IV.

CREDNER, Hermann. Die Kreide von New Jersey.

Zeitsch. d. D. geol. Gesell., Vol. XXII, 1870, pp. 191–251; plate.

DAWSON, George Mercer. On the Occurrence of Foraminifera, Coccoliths, and Rhabdoliths in the Cretaceous Rocks of Manitoba.

Canad. Nat., n. s., Vol. VII, 1874, pp. 252–257; figures.

Digitized by Google

DAWSON, George Mercer. On the Microscopic Structure of Certain Boulder Clays, and the Organisms contained in them.

Thirteenth Ann. Rept. Geol. and Nat. Hist. Sur. Minn. for 1884 (1885), pp. 150–163.

DAWSON, John William. Notice of Tertiary Fossils from Labrador, Maine, etc.

Canad. Nat , Vol. V, 1860, pp. 188–200; figures.

—— On some New Species of Fossil Protozoa from Canada.

Proc. Am. Assoc. Adv. Sci., Vol. XXIV, 1876, pp. 100–106; figures.

EGGER, Johann Georg. Die Foraminiferen der Miocän-Schichten bei Ortenburg in Nieder-Bayern.

Neues Jahrb. f. Min., etc., 1857, pp. 266–311, Pls. V–XV.

EHRENBERG, Christian Gottfried. Ueber die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen.

Abhandl. königl. Akad. Wiss. Berlin for 1838, 1839, pp. 59–147, Pls. I–IV.

—— Verbreitung und Einfluss des microscopischen Lebens in Süd- und Nord-Amerika.

Abhandl. k. Akad. Wiss. Berlin for 1841, 1843, pp. 291–446, Pls. I–IV.

—— Ueber das mikroscopische Leben in Texas.

Bericht k. preuss. Akad. Wiss. Berlin, 1849, pp. 87–91.

—— Mikrogeologie, 2 vols., 1854; 40 plates.

See PARKER, W. K., et al., Ann. Mag. Nat. Hist., Vols. IX, X, 1872.

ENGELMANN, Wilhelm. Bibliotheca Historico-Naturalis, 1846.

Section Protozoa.

GABB, William M. Catalogue of the Invertebrate Fossils of the United States, with References.

Issued as a separate publication of the Proceedings Acad. Nat. Sci. Philadelphia for 1859 (1860), pp. 1–20.

—— Descriptions of New Species of American Tertiary and Cretaceous Fossils.

Jour. Acad. Nat. Sci. Philadelphia, n. s., Vol. IV, 1860, pp. 375–406.

—— and HORN, G. H. Monograph of the Fossil Polyzoa of the Secondary and Tertiary Formations of North America.

Jour. Acad. Nat. Sci. Philadelphia, n. s., Vol. V, pt. 2, 1862, p. 179, Pl. XXI, fig. 71.

GEINITZ, Hans Bruno. Characteristik der Schichten und Petrefaction des Sächsisch-böhmischen Kreidegebirges; second edition, 1850.

HEILPRIN, Angelo. Notes on Some New Foraminifera from the Nummulitic Formation of Florida.

Proc. Acad. Nat. Sci. Philadelphia, 1884, pp. 321–332; figures.

JOHNSON, H. A., and THOMAS, B. W. Report of the Committee on the Microscopic Organisms in the Boulder Clays of Chicago and Vicinity.

Bull. Chicago Acad. Sci., Vol. I, No. 4, 1884, pp. 35–40; figures.

Digitized by Google

JONES, Thomas Rupert. Remarks on the Foraminifera, with Especial Reference to their Variability of Form, illustrated by the Cristellarians.

Monthly Microsc. Jour., Vol. XV, 1876, pp. 61–92, Pls. CXXVIII, CXXIX.

—— and PARKER, W. K. On the Foraminifera of the Family Rotalinæ (Carpenter) found in the Cretaceous Formation, with Notes on their Tertiary and Recent Representatives.

Quart. Jour. Geol. Soc. London, Vol. XXVIII, 1872, pp. 103–131.

—— —— and BRADY H. B. A Monograph on the Foraminifera of the Crag. Part I.

Paleontographical Soc., Vol. XIX, 1866, pp. 1–72, Pls. I–IV.

—— and SHERBORN, C. D. Remarks on the Foraminifera, with Especial Reference to their Variability of Form, illustrated by the Cristellarians; Part II.

Jour. Royal Microsc. Soc. London, ser. 2, Vol. VII, 1887, pp. 545–557.

JUKES-BROWNE, A. J. The Origin of Greensand.

Science Gossip, 1876, pp. 30, 170.

KARRER, Felix. Ueber ein Vorkommen von oberer Kreideformation in Leitzersdorf bei Stockerau, und deren Foraminiferenfauna.

Jahrb. k. k. geol. Reichsanst., Vol. XX, 1870, pp. 157–184, Pls. X, XI.

LEA, Isaac. Contributions to Geology, 1833, pp. 227, Pls. I–VI.

LEIDY, Joseph. Foraminifera of the Coast of New Jersey.

Proc. Acad. Nat. Sci. Philadelphia, 1878, p. 292.

LYELL, Charles. Notice of the Foraminifera of the Cretaceous Beds of New Jersey.

Quart. Jour. Geol. Soc. London, Vol. I, 1845, pp. 55–60; figures.

MEEK, Fielding Bradford. Check List of the Invertebrate Fossils of North America; Cretaceous Formation.

Smithsonian Mis. Col., Vol. VII, 1864, No. 177, pp. 26.

—— Synopsis of the Invertebrate Fossils of the Cretaceous Formation of New Jersey.

Appendix A, Geology of New Jersey, 1868, p. 721.

MORTON, Samuel G. Synopsis of the Organic Remains of the Cretaceous Group, 1834; Plates.

—— Description of Some New Species of Organic Remains of the Cretaceous Group of the United States; with a Tabular Review of the Fossils hitherto discovered in this Formation.

Jour. Acad. Nat. Sci. Philadelphia, Vol. VIII, pt. 2, 1842, pp. 207–227, Pls. X, XI.

D'ORBIGNY, Alcide Dessalines. Tableau méthodique de la classe des céphalopodes.

Annales Sci. Nat., Vol. VII, 1826, pp. 245–314, Pls. X–XVII.

—— Voyage dans l'Amérique Méridionale—Foraminifères.

Vol. V, pt. 5, 1839, pp. 1–86, Pls. I–IX.

Digitized by Google

D'ORBIGNY, Alcide Dessalines. Mémoire sur les foraminifères de la craie blanche du bassin de Paris.

Mém. Soc. Géol. France, Vol. IV, 1840, pp. 1–51, Pls. I–IV.

—— Foraminifères fossiles du bassin tertiaire de Vienne, Pls. I–XXI.

PARKER, W. K., and JONES, T. R. On Some Foraminifera from the North Atlantic and Arctic Oceans, including Davis Straits and Baffin's Bay.

Phil. Trans.(1864), 1865, pp. 321–441, Pls. XII–XIX.

—— —— Description of Some Foraminifera from the Coast of Norway.

Ann. and Mag. Nat. Hist., ser. 2, Vol. XIX, 1857, pp. 273–303, Pls. X, XI.

—— —— BRADY, H. B, and KIRKBY, J. W. On the Nomenclature of the Foraminifera.

Ann. and Mag. Nat. Hist., 1859–1872, ser. 3, Vol. III, to ser. 4, Vol. X.

POURTALES, L. F. de. On the Distribution of the Foraminifera on the Coast of New Jersey, as shown by the Off-shore Soundings of the Coast Survey.

Proc. Am. Assoc. Adv. Sci., Vol. III, 1850, pp. 84–88.

—— The Gulf Stream. Characteristics of the Atlantic Sea-bottom off the Coast of the United States.

Rept. Supt. U. S. Coast Survey for 1869 (1872), pp. 220–225.

REUSS, Aguste E. In H. B. Geinitz, Grundriss der Versteinerungskunde, 1845–46, pp. 635–686, Pl. XXIV.

—— Die Versteinerungen der böhmischen Kreideformation, 1845–46; Plates.

—— Neue Foraminiferen aus den Schichten des österreichischen Tertiärsbeckens.

Denks. Akad. Wiss. Wien, Vol. I, 1850, pp. 365–390, Pls. XLVI–LI.

—— Die Foraminiferen und Entomostraceen des Kreidemergels von Lemberg.

Haidinger's Nat. Abhandl., Vol. IV, 1851, pp. 17–52, Pls. I–V. (Referred to as Pls. II–VI.)

—— Ueber die fossilen Foraminiferen und Entomostraceen der Septarienthone der Umgegend von Berlin.

Zeits. d. D. Geol. Gesell., Vol. III, 1851, pp. 49–92, Pls. III–VII.

—— Beiträge zur Charakteristik der Kreideschichten in den Ostalpen besonders im Gosanthale und am Wolfgangsee.

Denks. Akad. Wiss. Wien, Vol. VII, Abth. 1, 1854, pp. 156, Pls. 31.

—— Beiträge zur Charakteristik der Tertiärschichten des nördlichen und mittleren Deutschlands.

Sitz. Akad. Wiss. Wien, Vol. XVIII, 1855, pp. 197–272, Pls. I–XII.

—— Ein Beitrag zur genauren Kenntniss der Kreidegebilde Mecklenburgs.

Zeits. d. D. geol. Gesell., Vol. VII, 1855, pp. 261–292, Pls. VIII, IX.

Digitized by Google

REUSS, Aguste E. Die marinen Tertiärschichten Böhmens und ihre Versteinerungen.

Sitz. Akad. Wiss. Wien, Vol. XXXIX, 1860, pp. 207–284, Pls. I–VIII (Pl. III).

—— Die Foraminiferen der Westphälischen Kreideformation.

Sitz. Akad. Wiss. Wien, Vol. XL, 1860, pp. 147–238, Pls. I–XIII.

—— Beiträge zur tertiären Foraminiferen-Fauna. I. Die Foraminiferen des Crag's von Antwerpen (pp. 355–364). II. Die Foraminiferen von Dingden in Westphalen (pp. 364–370).

Sitz. Akad. Wiss. Wien, Vol. XLII, 1860, Pls. I, II (see 1864).

—— Die Foraminiferen des senonischen Grünsandes von New Jersey.

Sitz. Akad. Wiss. Wien, Vol. XLIV, Abth. 1, 1861, pp. 334–340, Pls. I–VIII.

—— Die Foraminiferen des nord-deutschen Hils und Gault.

Sitz. Akad. Wiss. Wien, Vol. XLVI, Abth. 1, 1862 (1863), pp. 5–100, Pls. I–XIII.

—— Beiträge zur Kenntniss der tertiären Foraminiferenfauna.

Sitz. Akad. Wiss. Wien, Vol. XLVIII, Abth. 1, 1863, pp. 36–69, Pls. I–VIII.

—— Zur Fauna des deutschen Ober-Oligocäns, I Abth.

Sitz. Akad. Wiss. Wien, Vol. L, Abth. 1, 1864 (1865), pp. 435–482, Pls. I–V.

—— Die Foraminiferen und Ostrakoden der Kreide am Kanara-See bei Küstendische.

Sitz. Akad. Wiss. Wien, Vol. LII, Abth. 1, 1865 (1866), pt. 1, pp. 445–470, Plate.

—— Die Foraminiferen, Anthozoen, und Bryozoen des deutschen Septarienthones.

Denks. Akad. Wiss. Wien, Vol. XXV, 1865, pp. 117–204, Pls. I–XI.

—— Die Bryozoen und Foraminiferen des unteren Quaders.

Palæontographica, Vol. XX, pt. 1, 1871–1875, pp. 97–142, Pls. XXIV–XXXIII.

ROEMER, Ferdinand. Die Kreidebildungen von Texas, 1852, p. 86, Pl. X, fig. 7.

ROEMER, Friedrich Adolph. Die Versteinerungen des norddeutsches Kreidegebirges, 1840–41, pp. 145, Pls. I–XVI (Pl. XV). Neue Kreide-Foraminiferen.

Neues Jahrb. f. Min., etc., 1842, pp. 272, 273, Pl. VII B.

SCHWAGER, Conrad. Saggio di una classificazione dei Foraminiferi avuto riguardo alle loro famiglie naturali.

Boll. R. Com. Geol. Ital., 1876, pp. 475–485; 1877, pp. 18–24; plate

SCIENCE GOSSIP, 1870. Recent Foraminifera, pp. 9–12, figs. 17–31; Chalk Foraminifera, pp. 81–83, figs. 75–94; d'Orbigny's Foraminifera, pp. 106–108, figs. 103–119; d'Orbigny's Foraminifera, pp. 155–157, figs. 138–156.

SEGUENZA, G. Studi geologici e paleontologici sul cretaceo medio dell' Italia meridionale.

Atti R. Accad. Lincei., ser. 3, Vol. XII, 1879, pp. 65–214, Pls. I–XXI.

Digitized by Google

SHERBORN, C. D. A Bibliography of the Foraminifera, Recent and Fossil, from 1565 to 1888. London, 1888.

—— An Index to the Genera and Species of the Foraminifera.

Part I, A–Non. Smithsonian Misc. Coll. No. 856, 1893. Part II, Non–Z. Smithsonian Misc. Coll. No. 1031, 1896. Part of Vol. XXXVII, not yet published.

—— and CHAPMAN, F. On Some Microzoa from the London Clay exposed in the Drainage Works. Piccadilly, London, 1885.

Jour. Royal Microsc. Soc., ser. 2, Vol. VI, 1886, pp. 737–764, Pls. I–III.

SOLLAS, W. J. On the Perforate Character of the Genus Webbina, etc.

Geol. Mag., Decade II, Vol. IV, No. 3, March, 1877, pp. 102–105, Pl. VI.

TASCHENBERG, O. Bibliotheca Zoologica II, Third Lief., 1887. Protozoa, pp. 880–925.

TERSUEM, Olry. Les foraminifères de l'Eocène des environs de Paris.

Mém. Soc. Géol. France, ser. 3. Vol. II, Mém. 3, 1882, pp. 193, Pls. IX–XXVIII.

VERRILL, A. E. Characters of the Deep-sea Deposits of the Eastern American Coasts.

Amer. Nat., Vol. XIX, 1885, pp. 69, 70.

WHITE, C. A. Bibliography of North American Invertebrate Palæontology, 1878, pp. 132.

WILLIAMSON, William Crawford. On the Recent Foraminifera of Great Britain. Ray Society, 1858; plates.

WOODWARD, Anthony. A Bibliography of the Foraminifera, Recent and Fossil, including Eozoön and Receptaculites, 1565–1886.

Fourteenth Ann. Rept. Geol. Nat. Hist. Surv. Minn. for 1885, pp. 167–311, 1886.

—— Cretaceous Foraminifera of New Jersey, Part I.

Jour. N. Y. Micr. Soc., Vol. VI, No. 2, Apr., 1890, pp. 45–55.

—— Cretaceous Foraminifera of New Jersey, Part II.

Jour. N. Y. Micr. Soc., Vol. X, No. 4, Oct., 1894, pp. 91–141.

—— Foraminifera found in the Alabama Chalk.

Geol. Surv. Ala., Report of Geol. Coastal Plain, 1894, p. 289.

—— and THOMAS, B. W. On the Foraminifera of the Boulder Clay taken from a Well Shaft 22 feet deep, Meeker County, Central Minnesota.

Thirteenth Ann. Rept. Geol. and Nat. Hist. Surv. Minn. for 1884, pp. 164–177, Pls. III, IV.

—— —— The Microscopical Fauna of the Cretaceous in Minnesota, with Additions from Nebraska and Illinois.

Final Rept. Minn. Geol. and Nat. Hist. Surv. Vol. III, 1893, pp. 23–54, Pls. C–E.

WOOLMAN, Lewis. Microsc. Bull. Queen & Co., Vol. V, No. 6, 1888, p. 41.

Digitized by Google

ZITTEL, Karl A. von. Handbuch der Palæontologie, 1876–1880, Band I, Abth. 1, pp. 61–114; pp. 723–732.

DESCRIPTIVE TERMS.

The following descriptive terms, adopted in this memoir, are taken, with some modification, from the report on the Recent Foraminifera of Great Britain, by Prof. W. C. Williamson.[1] The figures employed have been copied, but the lettering has been changed.

The *length* is measured in the direction or axis of growth, as indicated by the line A B in fig. 1 of Pl. I, and the *breadth* by a line at right angles to the former one, C D in the same figure.

The above terms are applicable for evolute and convolute types, but in certain forms, either monothalamous and rounded or when the growth of chambers is around a central aperture, it is more convenient to use the term *diameter*.

The separate divisions of a shell or test are spoken of as *segments*, designated in fig. 1 of Pl. I as P, I, and U, of which P is the *primordial* and U the *ultimate* segment, while I, holding an intermediate position, is known as an *intermediate* segment. That part of the external surface nearest the end of the ultimate segment is called the *anterior margin* (fig. 1, *a*), while the opposite end is referred to as the *posterior margin* (fig. 1, *p*). These terms have a direct reference to the direction of growth.

The various segments are separated from one another by partitions called *septa*, and these are usually indicated externally by more or less definite constrictions known as *septal lines* (fig. 1, *s*). In old age these constrictions often become filled up and appear as ridges instead of depressions. The *septal plane* is the superficial area of each septum and corresponds in dimensions with the entire breadth of the constricted portion of the shell (fig. 1, *s p*).

Each septum is provided with one or more openings known as *septal apertures*, which serve as a means of communication between contiguous segments. The perforation of the anterior end of the ultimate segment is spoken of as the *oral aperture* (fig. 1, *o a*).

The different views of the shell are referred to as the *anterior*, *lateral*, and *periphero-lateral* aspects. The anterior aspect is seen by looking down upon the septal plane of the ultimate segment; the lateral aspect shows the shell from one side, as in fig. 1; while the periphero-lateral aspect is seen in depressed forms where the shell is viewed from its thin edge, as in fig. 3 of Pl. II. When the segments are arranged in a complete circuit around the primordial cell they constitute a *convolution*. Each convolution joins a contiguous one by a spiral line called the *spiral suture* (Pl. I, fig. 2, *m*). In the simplest case these convolutions are arranged in a single plane, but in more complex types each convo-

[1] On the Recent Foraminifera of Great Britain, Ray Society, London, 1858, pp. 14–18.

Digitized by Google

lution is formed in a different plane, and a *trochoid* type of shell results, as in Discorbina (fig. 4). The word "rotaliform" is used to express a form in which all of the segments are visible upon the superior surface, but only those of the last convolution are visible upon the inferior surface.

Each side of the shell in convolute types presents a *lateral surface* (fig. 3, L L). The sides of the shell at right angles to these lateral surfaces constitute the *peripheral margin* (fig. 3, *x x*). The margin is very varied in shape, and the angle formed by its outline is called the *peripheral angle.*

The depression formed in the center of the shell is called the *umbilicus.* Sometimes, instead of being depressed the early chambers are raised or elevated into a sort of boss by deposit of exogenous material, but the area is always referred to as the umbilical area, whether raised or depressed.

The terms *superior* and *inferior* lateral surface are constantly referred to and should be clearly understood. When a form continues its convolutions in a single plane both sides remain similar and there is no distinction between the upper and lower lateral surfaces, but when the coils are arranged spirally, as in trochoid types, there is a difference between the surfaces and it becomes necessary to indicate by the terms "superior" and "inferior" the surface referred to.

The term *superior lateral surface* (fig. 4, S L S) is the one in which the primordial segment is situated, while the opposite side, in which the form is extending its growth, is the *inferior lateral surface* (fig. 4, I L S). There are some exceptions to this rule, as, for example, in certain Truncatulina types, which are approximately flat upon the side that bears the primordial segment, as if the shell were cut in halves, the line of division passing through the center of the primordial segment. In such cases the lower (flat) surface becomes the superior lateral side.

The term *distal end* refers to the portion of the shell which carries the oral aperture and is usually farthest removed from the primordial segment. The portion of the shell in which the primordial segment is situated is called the *proximal end.*

It is often necessary to speak of a given type of shell, and therefore the following terms are employed in this report:

1. Nodosarian (Pl. I, fig. 1). Chambers typically arranged in a straight row.

2. Nautiloid (Pl. I, figs. 2 and 3). Chambers wound in a horizontal manner, forming an equilateral spire.

3. Trochoid (Pl. I, fig. 4). Chambers wound around one side of the primordial segment in an inequilateral spire.

4. Textularian (Pl. I, fig. 5). Chambers arranged alternately in an elongated series (biserial).

5. Milioline (Pl. I, fig. 6). Chambers wound spirally about an imaginary axis.

Digitized by Google

DESCRIPTION OF GENERA AND SPECIES.

Subkingdom PROTOZOA.

Class RHIZOPODA.

Order FORAMINIFERA.

Family LITUOLIDÆ.

Subfamily LITUOLINÆ.

Genus HAPLOPHRAGMIUM Reuss.

HAPLOPHRAGMIUM CONCAVUM Bagg.

PLATE II, figs. 1a, 1b.

Test arenaceo-siliceous, rough, of a dull-gray color; consisting of eight or nine chambers, which are concave upon their inner margin, giving the form an approximately triangular outline in transverse section; chambers variable in size; ultimate chamber largest and very slightly elevated in the central portion; septal lines straight, marked by definite deep constrictions; aperture a large elongated oval opening, situated toward the outside edge of the ultimate chamber and nearer the convex side.

Length, 1 mm.; breadth, 0.43 mm.

Locality.—Rancocas formation, Blue Ball, New Jersey.

Geological distribution.—Cretaceous.

HAPLOPHRAGMIUM IRREGULARE (Roemer).

Spirolina irregularis Roemer, 1840–41; Verstein. norddeutsch. Kreide, p. 98, Pl. XV, fig. 29.

Haplophragmium irregulare Reuss, 1860; Sitz. Akad. Wiss. Wien., Vol. XL, p. 219, Pl. X, fig. 9; Pl. XI, fig. 1.

Test arenaceous, rough, flask-shaped; chambers unequal and irregular, at first involute, then evolute and arranged in an elongated series, closely set, numerous (about fifteen), narrow, separated by straight depressed septa; aperture divided.

Length, 2.6 mm.; breadth, 0.6–0.9 mm.

Locality.—Rancocas formation, Vincentown, New Jersey. Rare.

Geological distribution.—Cretaceous.

Subfamily TROCHAMMININÆ.

Genus TROCHAMMINA Parker and Jones.

TROCHAMMINA INFLATA (Montagu).

Nautilus inflatus Montagu, 1808; Test. Brit. Suppl., p. 81, Pl. XVIII, fig. 3.

Trochammina inflata Brady, 1884; Chal. Rept., Vol. IX, p. 338, Pl. XLI, fig. 4, a–c.

"Test free; trochoid or convex, depressed, rotaliform; consisting of about three convolutions, the outermost of which is formed of five or six very ventricose segments with deeply excavated septal lines. Inferior

Digitized by Google

face somewhat concave, with sunken umbilicus; peripheral margin lobulated. Aperture small, arched; situated on the inferior side of the final segment, close to the previous convolution, a little within the periphery. Color pale brown, the small primary segments much darker than the rest." (Brady, loc. cit.)

The above description agrees closely with the New Jersey specimens, but the color is rather a yellowish white than a brown, and the external view shows only two convolutions instead of three, as in Professor Brady's figure.

Diameter, 0.43 mm.

Locality.—Rancocas formation, Timber Creek, near Mullica Hill, New Jersey.

Geological distribution.—Lias to Recent.

Family TEXTULARIDÆ.

Subfamily TEXTULARINÆ.

TEXTULARIA Defrance.

TEXTULARIA AGGLUTINANS d'Orbigny.

Textularia agglutinans d'Orbigny, 1839; Foram. Cuba, p. 136, Pl. I, figs. 17, 18, 32–34.
Textularia agglutinans Brady, 1884; Chal. Rept., Vol. IX, p. 363, Pl. XLIII, figs. 1–3; var., figs. 4, 12.

Test agglutinous, elongated, of a dull gray color, laterally convex; chambers rather numerous, ten to twelve in long specimens; septa nearly straight; aperture semilunar.

Length, 2.37 mm.

Locality.—Rancocas formation, Vincentown, Mullica Hill, Timber Creek, New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This is a rather common species at Vincentown, where it occurs in the "lime sand." It is interesting to see the small, smooth glauconite grains which help to form the shell substance.

TEXTULARIA AGGLUTINANS var. PORRECTA Brady.

Textularia agglutinans var. *porrecta*, Brady, 1884; Chal. Rept., Vol. IX, p. 364, Pl. XLIII, fig. 4.

Test much elongated, agglutinous, of nearly uniform width; chambers more numerous than in *Textularia agglutinans*, otherwise both forms are very similar.

The New Jersey specimens are not quite so elongated as the figure in the *Challenger* Report.

Length, 2 mm.; breadth, 0.6 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This form has been described by Tyrrell from the Cretaceous rocks of Canada.

Digitized by Google

TEXTULARIA GIBBOSA d'Orbigny.

Textularia gibbosa d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 262, No. 6.
Textularia gibbosa Terrigi, 1891; Mem. R. Com. G. Regno, Vol. IV, pt. 1, p. 68, Pl. I, fig. 10.

Test ovate elongate, smooth, of a dull-gray color; transverse section round; shell composed of only four chambers in each series; septal lines arched, scarcely discernible externally; aperture a median semilunar arch in the ultimate segment.

Length, 0.9–1 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous to Recent.

TEXTULARIA GLOBULOSA Ehrenberg.

Textularia globulosa Ehrenberg, 1839; Abhandl. k. Ak. Wiss. Berlin (1838), p. 135, Pl. IV, fig. *β*.
Textularia globulosa Woodward and Thomas, 1885; 13th Ann. Rept. Geol. Nat. Hist. Survey Minnesota for 1884, p. 166, Pl. III, figs. 1-5.

Test small, consisting of a few smooth, spherical, or globular chambers; suture lines deep; shell posteriorly acute, anteriorly obtuse.

Length unknown.

Locality.—Monmouth formation, Freehold, New Jersey. Rare.

Geological distribution.—Cretaceous.

It has been impossible to find shells in perfect preservation, since the constructions between the chambers are so pronounced that the chambers are easily broken off, but the few globular chambers we do find are sufficient for the determination of the species.

TEXTULARIA GRAMEN d'Orbigny.

Textularia gramen d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 248, Pl. XV, figs. 4–6.
Textularia gramen Brady, 1884; Chal. Rept., Vol. IX, p. 365, Pl. XLIII, figs. 9, 10.

Test arenaceous, rough externally, stoutly built, laterally compressed, margin subangular; five to six wide chambers, very slightly convex; posterior end neatly rounded; general outline very similar to *Textularia hauerii*, but distinguished from that species by its more angular lateral edges, and differing from *Textularia abbreviata*, which it also resembles, in being less short and thick.

Length, 1 mm.; breadth, 0.52 mm.

Locality.—Rancocas formation, Vincentown, Timber Creek, etc., New Jersey.

Geological distribution.—Cretaceous to Recent.

TEXTULARIA SAGITTULA Defrance.

Textularia sagittula Defrance, 1824; Dict. Sci. Nat., Vol. XXXII, p. 177; 1828, Vol. LIII, p. 344; Atlas, Conch., Pl. XIII, fig. 5.
Textularia sagittula Brady, 1884; Chal. Rept., Vol. IX, p. 361, Pl. XLII, figs. 17, 18.

Digitized by Google

Test elongated, strongly compressed, with sharp-angled peripheral margin; chambers numerous (12 to 15), closely set, visible externally in the upper portion only; septal lines almost straight, curving very gently toward the central portion; aperture linear.

Length, 0.45–0.55 mm.

Locality.—Rancocas formation, Vincentown, New Egypt, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

TEXTULARIA TURRIS d'Orbigny.

Textularia turris d'Orbigny, 1840; Mém. Soc. Géol. France, ser. 1., Vol. IV, p. 46, Pl. IV, figs. 27, 28.

Textularia turris Brady, 1884; Chal. Rept., Vol. IX, p. 366, Pl. XLIV, figs. 4, 5.

Test nearly round in transverse section, elongate, conical, rugose, tapering, anteriorly truncate; chambers numerous, complanate, somewhat irregular, quite distinct at the distal end.

Length, 1 mm.

Locality.—Rancocas formation, Vincentown, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

Genus VERNEUILINA d'Orbigny.

VERNEUILINA POLYSTROPHA (Reuss).

Bulimina polystropha Reuss, 1845–46; Verstein. böhm. Kreide, pt. 2, p. 109, Pl. XXIV. fig. 53.

Verneuilina polystropha Brady, 1884; Chal. Rept., Vol. IX, p. 386, Pl. XLVII, figs. 15–17.

Test arenaceous, rough, somewhat triangular, composed of only a few chambers, which increase very rapidly in size from below downward; aperture a central arched opening in the ultimate segment.

Length, 0.43 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous to Recent.

VERNEUILINA TRIQUETRA (Münster).

Plate II, fig. 2.

Textularia triquetra Münster, 1838; in Roemer's paper, Neues Jahrb., p. 384, Pl. III, fig. 19.

Textularia atlantica Bailey, 1851; Smithsonian Contrib., Vol. II, art. 3, p. 12, figs. 38–43.

Verneuilina triquetra Brady, 1884; Chal. Rept., Vol. IX, p. 383, Pl. XLVII, figs. 18–20.

Test composed of coarse sand grains and scattered grains of glauconite, triserial; chambers with flattened sides, definitely marked by sutures, eight to ten in each series; transverse section an almost equilateral triangle; surface rugose, and the coarse sand grains are interspersed with grains of glauconite; septal lines arched in the central

Digitized by Google

portion and directed downward toward the edges; triangular edges not always straight, but curved somewhat in passing from the primordial to the distal end; aperture a median elongated slit with a depressed margin.

The shell is of a dull-gray color, and attains large size.

An analysis of *Verneuilina triquetra* gave 41.37 per cent of silica. The sand grains are very firmly cemented by calcareous substance which forms the base of the shell.

It is a very common species.

Length, 3.13 mm.

Locality.—Rancocas formation, Vincentown, Mullica Hill, and Timber Creek, New Jersey. Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

Genus TRITAXIA Reuss.

TRITAXIA TORTILIS (Reuss).

Bulimina tortilis Reuss, 1861; Sitz. Akad. Wiss. Wien, Vol. XLIV, pt. 1, p. 338, Pl. VIII, fig. 3, a, b.

Test small, trihedral; chambers few, five to seven in each series, somewhat inflated and depressed at the septal lines; peripheral margins rather sharp; primordial end bluntly pointed; ultimate segment large, overreaching, and bearing the elliptical aperture near the upper part of the septal face.

Length, 0.52 mm.

Locality.—Rancocas formation, Swedesboro, New Jersey.

Geological distribution.—Cretaceous.

TRITAXIA TRICARINATA (Reuss).

Textularia tricarinata Reuss, 1845–46; Verstein. böhm. Kreide, pt. 1, p. 39, Pl. VIII, fig. 60.

Tritaxia tricarinata Brady, 1884; Chal. Rept., Vol. IX, p. 389, Pl. XLIX, figs. 8, 9.

Test tricarinate; lateral surfaces slightly concave, consisting of a few (four or five) rather indistinct segments in each row; aperture central, rotund, in a short elevated neck.

Length, 1.3 mm.

Locality.—Rancocas formation, Swedesboro, Timber Creek, New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

Genus GAUDRYINA d'Orbigny.

GAUDRYINA PUPOIDES d'Orbigny.

Gaudryina pupoides d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 44, Pl. IV, figs. 22–24.

Gaudryina pupoides Brady, 1884; Chal. Rept., Vol. IX, p. 378, Pl. XLVI, figs. 1–4.

"*Gaudryina pupoides* is an easily recognized species. Its dimorphous mode of growth is generally very apparent, and its variability is

Digitized by Google

limited to such features as the number of segments, the relative length and breadth of the test, and the degree of lateral compression. In recent shells the walls are thin and calcareous, smooth externally, and almost invariably of a grayish hue; fossil specimens sometimes exhibit slightly rough exterior. In form and position the aperture resembles that of the typical Textulariæ, but it is often surrounded by a raised tip or border." (Brady, loc. cit.)

Length, 2 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

Genus CLAVULINA d'Orbigny.

CLAVULINA COMMUNIS d'Orbigny.

Clavulina communis d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 268, No. 4.

Clavulina communis, d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne; p. 196, Pl. XII, figs. 1, 2.

Test elongate, straight, rough externally and arenaceous; early segments triquetrous, spiral, and forming a pointed apex, a transverse section of which is round, not angular as in *Clavulina parisiensis* d'Orbigny; anterior chambers marked by depressed septa, somewhat irregular in size, but the ultimate one is the largest; aperture normally a central opening in a short tubular neck of the ultimate chamber.

Length, 2.1 mm.

Locality.—Rancocas formation, Brownsville, New Jersey.

Geological distribution.—Upper Cretaceous to Recent.

CLAVULINA PARISIENSIS d'Orbigny.

Clavulina parisiensis d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 268, No. 3; Modèle, No. 66.

Clavulina parisiensis Brady, 1884; Chal. Rept., Vol. IX, p. 395, Pl. XLVIII, figs. 14–18.

Test coarsely arenaceous, elongated, straight or nearly so; ultimate chambers nodosarian, short, marked by straight, somewhat depressed septa; primordial segments triquetrous as in *Clavulina communis* d'Orbigny, but wedge-shaped and triangular in outline instead of being rounded; aperture a central opening in a short tubular neck.

Length, 2.4 mm.

Locality.—Rancocas formation, Brownsville, New Jersey.

Geological distribution.—Cretaceous to Recent.

Occurs with the preceding not rarely in the lime sand of Brownsville.

Subfamily BULIMININÆ.

Genus BULIMINA d'Orbigny.

BULIMINA PUSCHI Reuss.

Bulimina puschi Reuss, 1851; Haidinger's Naturw. Abhandl., Vol. IV, pt. 1, p. 37, Pl. III, fig. 6.

Test elongate oval, obtusely rounded above, acutely rounded below,

Digitized by Google

shell wall very punctate; chambers rapidly increasing in size from below upward, irregularly wedge-shaped, moderately depressed at the sutures; aperture a comma-shaped slit near the margin of the ultimate segment.

Length, 0.5 mm.

Locality.—Monmouth formation, Freehold, New Jersey. Very rare.

Geological distribution.—Cretaceous.

BULIMINA VARIABILIS d'Orbigny.

Bulimina variabilis d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, pt. 1, p. 40, Pl. IV, figs. 9–12.

Bulimina variabilis Reuss, 1845–46; Verstein. böhm. Kreide, pt. 1, p. 37, Pl. VIII, figs. 56, 76, 77.

Test variable, ovate or oblong, very finely perforate; spire short, obtuse posteriorly; segments few, very narrow, slightly oblique; ultimate chamber ending in a flat surface; aperture oval, situated at the inner margin.

Diameter, 0.2–0.3 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

This small species from the New Jersey marl beds agrees closely with the figures of Professor Reuss. It has been recognized only in the lower marl bed at Freehold, and is a rare form.

Genus BOLIVINA d'Orbigny.

BOLIVINA PUNCTATA d'Orbigny.

Plate II, fig. 3.

Bolivina punctata d'Orbigny, 1839; Foram. Amér. Merid., p. 63, Pl. VIII, figs. 10–12.

Bolivina antiqua d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 240, Pl. XIV, figs. 11–13.

Bolivina punctata Brady, 1884; Chal. Rept., Vol. IX, p. 417, Pl. LII, figs. 18, 19.

Test elongate, textulariform, smooth, compressed, finely perforate, anterior end obtuse, posterior acute, lateral margins subcarinate; chambers five to seven in each series; septal lines depressed; aperture terminal, simple, oval.

Length, 0.35 mm.; greatest breadth, 0.15 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Monmouth formation, Freehold, and Bruere's pits on Crosswicks Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

This species is common at Freehold. It resembles *Bolivina textilaroides* Reuss in the small number of chambers and somewhat broader outline, but differs from this latter species in being much more oval in outline when seen in transverse section.

Digitized by Google

BOLIVINA TEXTILAROIDES Reuss.

Bolivina textilaroides Reuss, 1862; Sitz. Akad. Wiss. Wien, Vol. XLVI, p. 81, Pl. X, fig. 1.

Bolivina textilaroides Brady, 1884; Chal. Rept., Vol. IV, p. 419, Pl. LII, figs. 23–25.

Test textulariform; segments few in number, about six in each series; septal lines depressed, and the chambers somewhat inflated; surface smooth, finely punctate; peripheral margins rounded, and more or less lobulated.

Length, 1 mm.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This species is less common than *Bolivina punctata.*

Genus PLEUROSTOMELLA Reuss.

PLEUROSTOMELLA SUBNODOSA Reuss.

Nodosaria nodosa (pars) Reuss, 1845–46; Verstein. böhm. Kreide, pt. 1, p. 28, Pl. XIII, fig. 22.

Dentalina subnodosa (pars) Reuss, 1850; Haidinger's Naturw. Abhandl., Vol. IV, pt. 1, p. 24, Pl. I, fig. 9.

Pleurostomella subnodosa Brady, 1884; Chal. Rept., Vol. IX, p. 412, Pl. LII, figs. 12, 13.

Test elongate, almost straight, with somewhat irregular outline; chambers enlarging, slightly convex, separated by oblique sutures; ultimate chamber largest, shortly acute; primordial chamber smallest, rounded; aperture an elongated, naked, oval opening extending slightly down the side of the ultimate segment.

Length, 1 mm.

Locality.—Rancocas formation, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

Family LAGENIDÆ.

Subfamily LAGENINÆ.

Genus LAGENA Walker and Boys.

LAGENA GLOBOSA (Montagu).

Vermiculum globosum Montagu; Testac. Brit., 1803, p. 523.

Oolina simplex Reuss, 1851; Haidinger's Naturw. Abhandl., Vol. IV, pt. 1, p. 22, Pl. I, fig. 2.

Lagena globosa Reuss. 1863; Sitz. Akad. Wiss. Wien, Vol. XLVI, pt. 1, p. 318, Pl. I, figs. 1–3.

Lagena globosa Brady, 1884; Chal. Rept., Vol. IX, p. 452, Pl. LVI, figs. 1–3.

Test subglobular, elliptical or pyriform; surface smooth; finely perforate shell with thin, hyaline cell walls; anterior margin somewhat projecting, with aperture in an entorolenian neck.

Length, 2 mm.; breadth, 1.5 mm.

Locality.—Rancocas formation, Vincentown and Mullica Hill, New Jersey.

Geological distribution.—Jurassic to Recent.

Digitized by Google

Genus VITREWEBBINA Chapman.

"Test opaque to translucent, of a whitish or pale-brown color. Shell wall very finely perforated, consisting of a single hemispherical or pyriform chamber, or of a graduated series dispersed usually in a curved line, and adherent upon some foreign substance. The chambers are connected by stolon tubes, very distinctly seen on the under surfaces of the specimens which have become detached. The surface of the shell may be smooth, pitted, or, as in Dr. Sollas's specimen, tuberculate."[1]

VITREWEBBINA SOLLANI Chapman.

Plate II, figs. 5a, 5b.

Vitrewebbina sollasi Chapman, 1892; Geol. Mag., n. s., decade 3, Vol. IX, No. 2, Feb., pp. 53-54, Pl. II, fig. 4.

Test smooth, adherent, hyaline, finely perforate; consisting of one or many chambers arranged in a more or less curving irregular chain; chambers attached by stoloniferous tubes; aperture terminal in ultimate chamber; length variable, dependent upon the number of chambers.

Breadth, 0.2–0.6 mm.; shell diameter, 0.01 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous.

This is a very common form at Vincentown, and is frequently found adhering to *Flabellina sagittaria*, although often occurring on other shell fragments. Although the primordial chamber is generally the smallest and the ultimate the largest, there is no regularity of arrangement in regard to size of the chambers.

It was with some difficulty that the position of this form was determined. The structure of the shell substance alone separates it from *Trochammina irregularis* Carpenter,[2] but solution of the shell in hydrochloric acid failed to reveal any trace of arenaceous or siliceous material, although in some cases there was an inner coating of amorphous material remaining insoluble in the acid.

A form similar to the one under discussion is figured by Quenstedt[3] and described by him as *Bullopora rostrata* in the following words: "This consists of simple, small, dark hemispheres, united with each other through lengthened tubes. This tube often projects from the end cell like a beak, whence I have given it its name. Generally the pustules (chambers) increase in size, with now and then smaller ones between, while the primordial cell is similar to those succeeding." This species is described by Schwager[4] as *Placopsilina rostrata*, and is placed under the calcareous perforate division of the Dentaloidea.

---

[1] Chapman, Geol. Mag., n. s., decade 3, Vol. IX, No. 2, Feb. 1892, p. 53.

[2] Introduction to the Study of the Foraminifera, p. 142, Pl. XI, figs. 6–10.

[3] Der Jura, 1858, p. 580, Atlas, Pl. LXXIII, fig. 28.

[4] Bolletino del R. Comitato Geol. d'Italia, 1877, Vol. VIII, p. 18, Pl. fig. 12.

Digitized by Google

In the original description of the genus Placopsilina[1] no mention is made of the nature of the test, whether of arenaceous or calcareous composition, but later authorities (Brady[2]) consider the genus under arenaceous types of the Lituolidæ.

The tubulated structure of the genus Webbina, simulating the arenaceous Trochamminæ, is quite striking, and its calcareous composition in this case led to a discussion by Dr. W. J. Sollas,[3] "On the perforate character of the genus Webbina," etc., and the later establishment of a new genus, Vitrewebbina, by Frederick Chapman,[4] which I have adopted as a solution of the difficulty presented by this isomorphous form.

VITREWEBBINA LÆVIS (Sollas).

Plate II, figs. 4a, 4b.

Webbina lævis, Sollas, 1877; Geol. Mag., n. s., decade 2, Vol. IV, No. 3, March, pp. 103–104, Pl. VI, figs. 1–3.

Test very similar to *Vitrewebbina sollasi* in shape and general appearance, and differing from that species only in having no external marginal flange and in being somewhat more elevated. The form occurs with the preceding in the lime sand at Vincentown, but is not very common, while *Vitrewebbina sollasi* is rather plentiful.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous.

Subfamily NODOSARINÆ.

Genus NODOSARIA Lamarck.

NODOSARIA ACUMINATA (Reuss).

Dentalina acuminata Reuss 1860; Sitz. Akad. Wiss. Wien, Vol. XL, p. 181, Pl. I, fig. 7.

Test elongate, straight, tapering sharply; surface smooth; nine oval, regular chambers, rapidly increasing in size toward the distal end; primordial end acuminate; ultimate chamber globose, anteriorly prolonged into a distinct eccentric tube; septa depressed, transverse; aperture nipple-shaped.

The above species is very similar to *Dentalina subrecta* Reuss, but the latter has fewer segments and the proximal end less acuminate.

Length, 0.9 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous.

---

[1] d'Orbigny, A. D., Prodrome de Paleontologie Stratigraphique, 1850, Vol. II, p. 96.

[2] *Challenger* Report, 1884, Vol. IX, p. 314.

[3] Geol. Mag., n. s., decade 2, Vol. IV, No. 3, March, 1877, pp. 102–105.

[4] Geol. Mag., n. s., decade 3, Vol. IX, No. 2, Feb., 1892, p. 53.

Digitized by Google

NODOSARIA ADOLPHINULA (d'Orbigny).

Dentalina adolphinula d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 51, Pl. II, figs. 18–20.

Dentalina adolphinula Sherborn and Chapman, 1886; Jour. Roy. Micros. Soc., ser. 2, Vol. VI, p. 750, Pl. XV, figs. 11, *a*, *b*, 12.

Test composed of six or seven short, oval chambers, very strongly separated by septal constrictions. The anterior portions of the ultimate chambers are smooth, but upon the lower ends of these are two rows of spines or tubercles jutting out at a low angle from the surface. Upon the primordial segments these spines are found to cover the whole surface. Primordial chamber armed with a short spine; ultimate segment ending in a tubular neck, which carries the round aperture.

Length, 1 mm. and over.

Locality.—Rancocas formation, southeast Swedesboro, New Jersey.

Geological distribution.—Cretaceous to Recent.

This small nodosarian form is not uncommon in the lime-sand beds below Swedesboro.

NODOSARIA ANNULATA Reuss.

Nodosaria annulata Reuss, 1844; Geogn. Skizze Böhmen, Vol. II, pt. 1, p. 210.

Nodosaria annulata Reuss, 1845–46; Verstein. böhm. Kreide, pt. 1, p. 27, Pl. VIII, figs. 4, 67. Pl. XIII, fig. 21.

Test smooth and glistening, arcuate, very elongate, tapering sharply to a point toward the proximal end; chambers spherical, numerous, fifteen to twenty, more constricted and globose toward the ultimate chamber, which is prolonged somewhat in its upper portion and carries the round mammillate aperture; septa transverse, definitely depressed at the anterior end.

This is one of the largest of all our nodosarian types. It resembles the specimens of *Nodosaria obliqua*, but is easily distinguished from the latter by its smooth surface. The proximal end of the shell sometimes shows very faint striæ as indications of ribs, but these are never prominent, and are visible only under the microscope.

Length, over 10 mm. in long specimens; breadth of largest chamber, 1 mm.

Locality.—Monmouth formation, Freehold, New Jersey; Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous.

NODOSARIA COMMUNIS (d'Orbigny.)

Dentalina communis d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 254, No. 35.

Nodosaria communis Brady, 1884; Chal. Rept., Vol. IX, p. 504, Pl. LXII, figs. 19–22.

Test elongate, slightly arcuate, smooth; septa oblique, depressed; chambers numerous, ten to fifteen, convex anteriorly; aperture small, radiate, situated near the incurved margin.

Digitized by Google

Length, 3.26 mm.

Locality.—Monmouth formation, Cream Ridge, Bruere's pits on Crosswicks Creek, New Jersey; Rancocas formation, New Egypt, Mullica Hill, Timber Creek, New Jersey.

Geological distribution.—Permian to Recent.

NODOSARIA CONSOBRINA (d'Orbigny.)

Dentalina consobrina d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 46, Pl. II, figs. 1–3.

Nodosaria consobrina Brady, 1884; Chal. Rept., Vol. IX, p. 501, Pl. LXII, figs. 23, 24.

Test smooth, dentaline, attenuated, and graceful; chambers nine or ten, shorter and less distinct at the proximal end but becoming more definite above and more elongated; septa distinct, straight, or nearly so, becoming more marked in the proximal extremity; ultimate chamber somewhat prolonged into a neck which carries the oral aperture; proximal end very neatly rounded.

Length, 2 mm.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This slender little species is very closely allied to the emaciate variety found in the Rancocas marl beds, but it is not so elongated and has a much smaller number of chambers.

NODOSARIA CONSOBRINA var. EMACIATA Reuss.

Nodosaria (D.) *consobrina*, var. *emaciata*, Reuss, 1865; Denks. Akad. Wiss. Wien, Vol. XXV, p. 132, Pl. II, figs. 12, 13.

Nodosaria (D.) *consobrina*, var. *emaciata*, Brady, 1884; Chal. Rept., Vol. IX, p. 502, Pl. LXII, figs. 25, 26.

Test smooth, greatly elongated, tapering; segments numerous, short, elongate oval; similar to *Nodosaria consobrina*, but more elongated and slender; septa somewhat depressed, transverse, primordial end rounded; aperture mammillate, somewhat prolonged into a tube.

Length, 2 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

NODOSARIA FARCIMEN (Soldani).

Orthoceras farcimen Soldani, 1791; Testaceographia, Vol. I, pt. 2, p. 98, Pl. CV, Fig. O.

Dentalina farcimen Reuss, 1863; Bull. Acad. Roy. Belge, ser. 2, Vol. XV, p. 146, Pl. I, fig. 18.

Test arcuate, tapering, with from six to ten inflated segments, separated by deep, straight, transverse sutures. The latter quality separates this species from *Nodosaria communis*, in which the sutures are oblique. There is also an irregularity in the increase of the size of the

Digitized by Google

chambers noticeable in most specimens. The ultimate chamber is prolonged into a round tube which bears the oral opening.

Length, 2.82 mm.

Locality.—Rancocas formation, New Egypt, New Jersey.

Geological distribution.—Permian to Recent.

NODOSARIA FILIFORMIS d'Orbigny.

Nodosaria filiformis d'Orbigny, 1826; Ann. Sci. Natur., Vol. VII. p. 253, No. 14.
Dentalina gracilis d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 14, Pl. I, fig. 5.
Nodosaria filiformis Brady, 1884; Chal. Rept., Vol. IX, p. 500, Pl. LXIII, figs. 3–5.

Test slender, elongated, smooth, crenate; chambers numerous (12), distinct, elongate oval: septa transverse, nonoblique; aperture simple, round.

Length, 2.1 mm.

Locality.—Monmouth formation, Cream Ridge, Redbank, New Jersey; Rancocas formation, Mullica Hill, Timber Creek, New Jersey.

Geological distribution.—Lias to Recent.

NODOSARIA INDIFFERENS (Reuss).

Dentalina indifferens Reuss, 1863; Sitz. Akad. Wiss. Wien, Vol. XLVIII, pt. 1, p. 44, Pl. II, figs. 15, 16.

Test consisting of from six to eight smooth, short, inflated chambers of unequal size; primordial chamber larger than the succeeding one, obtusely rounded; ultimate chamber large and more constricted than any of the other chambers.

Length, 1.7 mm.

Locality.—Monmouth formation, Cream Ridge, New Jersey.

Geological distribution.—Cretaceous and Tertiary.

NODOSARIA INORNATA (d'Orbigny).

Dentalina inornata d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 44, Pl. I, figs. 50, 51.
Dentalina inornata Sherborn and Chapman, 1886; Jour. Roy. Microsc. Soc., ser. 2, Vol. VI, pt. 2, p. 750, Pl. XV, fig. 8.

Test smooth, gently tapering, with chambers distinct and more indented upon one side than upon the other; septa very oblique, and curving very slightly in the central, and more markedly so near the margin of the lowest end of each chamber; aperture nearer one side.

Only three segments preserved.

Length unknown.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous and Tertiary.

The New Jersey specimens are almost identical with the form figured by Sherborn and Chapman from the London clay of England.

Digitized by Google

According to Professor Brady, this species is considered to be identical with *Nodosaria communis* d'Orbigny, and is given by him as a synonym under that name, but it is here kept distinct for several reasons, as it is by Chapman and Sherborn.

NODOSARIA LÆVIGATA d'Orbigny.

Nodosaria (*Glandulina*) *lævigata* d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 252, Pl. X, figs. 1-3.

Glandulina lævigata d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 29, Pl. I, figs. 4, 5.

Nodosaria lævigata Brady, 1884; Chal. Rept., Vol. IX, pp. 490, 493, Pl. LXI, figs. 17-22, 32.

Test cylindrical, tapering rapidly to a point at the primordial chamber; shell smooth, consisting of five or six short, indistinct segments; septal lines transverse; aperture round, crenulate.

This small species occurs sparingly in the lime sand at Vincentown. The American specimens are very similar to the forms from Germany figured by Professor Reuss under the name *Glandulina elliptica*.[1]

Length, 0.65 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

NODOSARIA LONGISCATA d'Orbigny.

Nodosaria longiscata d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 32, Pl. I, figs. 10-12.

Test elongate, smooth, consisting of chambers greatly extended and united end to end by definite constrictions. The forms are never found of full length, owing to the weak jointing of the segments, which allows them to break apart very readily. The species is somewhat similar to *Nodosaria ovulata* Sherborn and Chapman, but the chambers are not angular at their base, as in the latter species.

Length unknown.

Locality.—Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous and Tertiary.

NODOSARIA MULTICOSTATA (d'Orbigny).

Dentalina multicostata d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 15, Pl. I, figs. 14, 15.

Test large, abruptly tapering, arcuate; surface marked by numerous (24 at the anterior end) sharp, distinct, longitudinal costæ, slightly twisted and irregular in their arrangement; chambers nine or ten, short, deeply constricted, becoming more distinct toward the proximal end; aperture small, rotund, ending in a definitely constricted neck surrounded by a crenulated margin.

Length, 4–5 mm.

[1] Sitz. Akad. Wiss. Wein, 1863, Vol. XLVIII, p. 47, Pl. III, figs. 29-31.

Digitized by Google

Locality.—Rancocas formation, Blue Ball, New Jersey.

Geological distribution.—Carboniferous to Cretaceous.

NODOSARIA NITIDA d'Orbigny.

Nodosaria nitida d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 254, No. 33.

Nodosaria nitida Parker, Jones, and Brady, 1871; Ann. Nat. Hist., ser. 4, Vol. VIII, p. 158, Pl. IX, fig. 44.

Nodosaria nitida Tate and Blake, 1876; Yorkshire Lias, p. 457, Pl. XVII, fig. 19.

"A small striate Nodosaria, deeply constricted at its septa and having few, distinct, oval, or fusiform segments. A less robust form than *Nodosaria scalaria*, and less neatly finished as to base and terminal neck than that species generally is." (Parker, Jones, and Brady, loc cit.)

Owing to the deep constrictions, this form is easily broken, and I have no specimens with more than three segments. The ribs are very distinct and elevated, and there are small intermediate striæ between some, but not all, of the main costæ. The aperture ends in a phialine neck.

Length (of the three ultimate segments), 2.82 mm.

Locality.—Rancocas formation, Blue Ball, New Jersey.

Geological distribution.—Lias to Recent (?).

NODOSARIA OBLIQUA (Linné).

Nautilus obliquus Linné, 1767; Syst. Nat., twelfth ed., pp. 281, 1163; 1788, ibid., thirteenth (Gmelins) ed., p. 3372, No. 14.

Nodosaria sulcata Nilsson, 1827; Petrefacta Suec., p. 8, Pl. IX, fig. 19.

Dentalina sulcata d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 15, Pl. I, figs. 10–13.

Dentalina steenstrupi Reuss, 1855; Zeits. deutsch. geol. Gesell., Vol. VII, p. 268, Pl. VIII, fig. 14a.

Dentalina sulcata Reuss; ibid., p. 269, Pl. VIII, fig. 14b.

Dentalina obliqua Jones, Parker, and Brady, 1866; Monograph Foram. Crag, Pal. Soc. Vol. XIX, p. 54, Pl. I, fig. 9.

Test very large, elongated, arcuate, tapering; septal lines depressed; numerous costæ upon the surface, which vary in size and number in different specimens; chambers numerous, ventricose, distinct; aperture central, radiate. Some specimens end in a spine at the distal end.

Length, 2–13.5 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Monmouth formation, Freehold, New Jersey; Rancocas formation, Vincentown, Blue Ball, Mullica Hill, Timber Creek, Harrisonville, New Egypt, New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Lias to Recent.

This species is very common in the New Jersey marl beds and is one of the few forms which are found in all the horizons of the Upper Cretaceous series.

The Matawan specimens are only 2 mm. in length.

Digitized by Google

NODOSARIA PAUPERATA (d'Orbigny).

Dentalina pauperata d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 46, Pl. I, figs. 57, 58.

Nodosaria pauperata Brady, 1884; Chal. Rept., Vol. IX, p. 500, woodcuts, fig. 14a, b, c.

Test smooth, somewhat arcuate, tapering very gradually; chambers quite uniform in size, ten or eleven in number, not constricted in the lower portion of the shell, but becoming distinct and more constricted as they approach the proximal end; ultimate segment prolonged, provided with a constricted tube-like neck which carries the round aperture.

Length, 2–3 mm.

Locality—Manasquan formation, Vincentown, New Jersey.

Geological distribution—Lias to Recent.

NODOSARIA POLYGONA Reuss.

Nodosaria polygona Reuss, 1855; Zeits. deutsch. geol. Gesell., p. 265, Pl. VIII, figs. 7, 8.

Test cylindrical, elongate, costate, tapering very gradually, straight or but slightly curved; chambers numerous, ten to sixteen, becoming more constricted and globose toward the ultimate segment; primordial chamber larger than the one succeeding, bulbous, mucronate; ultimate chamber terminates in a short tubular neck, in which the round oral aperture is situated; longitudinal costæ few in number, eight to ten, very distinct, and elevated and extending from end to end.

Length, sometimes 9 mm.

The specimens from the Matawan marl beds are small (1.1 mm. in length), and have only six chambers, and are rare, while the Rancocas forms are very numerous and are among the largest of the Nodosariæ from New Jersey.

Locality—Matawan formation, Marshalltown, New Jersey; Monmouth formation, Freehold, New Jersey; Rancocas formation, New Egypt, Blue Ball, Harrisonville, New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution—Cretaceous to Recent.

NODOSARIA RADICULA (Linné).

Nautilus radicula Linné, 1767; Syst. Nat., twelfth ed., pp. 285, 1164; 1788, ibid., thirteenth (Gmelin's) ed., p. 3373, No. 18.

Nodosaria radicula d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 252, No. 3; Model No. 1.

Nodosaria radicula Brady, 1876; Palæont. Soc., Vol. XXX, p. 124, Pl. X, figs. 6–16.

Test straight, elongated, tapering, composed of from four to seven subglobose segments; surface of shell smooth; septal lines transverse, depressed; aperture a nipple-shaped protuberance on the ultimate segment.

Length, 2 mm.

Locality.—Rancocas formation, Timber Creek, New Jersey.

Geological distribution.—Permian to Recent.

Digitized by Google

NODOSARIA RAPHANUS (Linné).

Nautilus raphanus Linné, 1767; Syst. Nat., twelfth ed., pp. 283, 1164; 1788, ibid., thirteenth (Gmelin's) ed., p. 3373, No. 16.
Nodosaria raphanus Silvestri, 1872; Nodos. Fos. Viv. d'Italia, p. 43, Pl. IV, figs. 67–81.
Nodosaria raphanus Brady, 1884; Chal. Rept., Vol. IX, p. 512, Pl. LXIV, figs. 6–10.

Test elongate, straight, somewhat tapering, stoutly built; surface marked by eight sharp, elevated, distinct costæ; chambers few in number, generally fewer than ten, not very distinct, since the septal lines are nonlimbate; aperture a semilunar arch, median, surrounded by a thickened border.

Length, 1 mm.

Locality.—Rancocas formation, southeast Swedesboro, Timber Creek, New Jersey.

Geological distribution.—Upper Trias to Recent.

NODOSARIA ROEMERI (Neugeboren.)

Dentalina roemeri Neugeboren, 1856; Denks. Akad. Wiss. Wien., Vol XII, pt. 2, p. 82. Pl. II, figs. 13–17.
Nodosaria roemeri, Brady, 1884; Chal. Rept., Vol. IX, p. 505, Pl. LXIII, fig. 1.

Test smooth, consisting of six or seven large chambers separated by nearly straight, slightly depressed sutures; primordial chamber rounded and rather blunt; ultimate chamber carrying the oral aperture nearer the incurved margin. Some specimens are slightly curved, but the curvature is never very great.

Length, 0.82 mm.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous to Recent.

NODOSARIA ROTUNDATA (Reuss.)

Glandulina rotundata Reuss, 1850; Denks. Akad. Wiss. Wien., Vol. I, p. 366, Pl. XLVI. fig. 2.
Glandulina obtussima Reuss, 1863; Sitz. Akad. Wiss. Wien., Vol. XLVIII, pt. 1, p. 66, Pl. VIII, figs. 92, 93.

Test oval, not much elongated, with rounded base, consisting of only two or three segments, usually two, of which the ultimate chamber is much the largest; surface of shell smooth and white; aperture small, rotund, crenulate, placed centrally in ultimate chamber.

Length, 1–3 mm.

This is not an uncommon form in the limes and at Vincentown. Our specimens agree very closely with those figured by Professor Reuss.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

NODOSARIA SCABRA (Reuss).

Dentalina scabra Reuss, 1850; Denk. Akad. Wiss. Wien, Vol. I, p. 367, Pl. XLVI, figs. 7, 8.

Test small, elongate, tapering; surface uniformly covered with raised longitudinal striæ, or tubercles, visible only under high power in

Digitized by Google

reflected light; chambers eight in number, strongly constricted, becoming quite spheroid in the upper portion; primordial chamber furnished with a long, delicate spine upon the inside edge of the line of flexure; ultimate chamber prolonged into a round phialine neck; aperture rotund.

Length, 1 mm.

Locality.—Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous and Tertiary.

Reuss describes this form as being very variable in character, and states that there are two extreme types, which would be considered distinct species were it not for the connecting forms. It is a rare species at Vincentown, and we can not state whether the American type is constant or not. The one described agrees very closely with Professor Reuss's figure.

NODOSARIA SPINULOSA (Montagu).

Nautilus spinulosus Montagu, 1808; Test. Brit. Suppl., p. 86, Pl. XIX, fig. 5.
Dentalina spinulosa Sherborn and Chapman, 1886; Jour. Roy. Microsc. Soc., ser. 2, Vol. VI, p. 751, Pl. XV, fig. 13.

Test slightly arcuate, elongate; surface marked by elevated rib-like spines, which cover the segments irregularly. These rib-like projections jut out prominently, especially on the posterior portion of each segment. Chambers somewhat constricted, ten or more in number on long specimens.

Length, 2.16 mm.

Locality.—Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Upper Cretaceous and Tertiary.

The specimens described by Professors Chapman and Sherborn were from the London clay.

NODOSARIA VERTEBRALIS (Batsch).

Nautilus (*Orthoceras*) *vertebralis* Batsch, 1791; Conch. Seasands, p. 3, No. 6, Pl. II, fig. 6, b.
Dentalina vertebralis Sherborn and Chapman, 1886; Jour. Roy. Microsc. Soc., ser. 2, Vol. VI, p. 752, Pl. XIV, fig. 39, *a*, *b*.

Test long, nearly straight; surface marked by slightly elevated longitudinal costæ, very slightly twisted; chambers eight in number, of uniform size, but tapering somewhat toward the primordial segment, unconstricted and marked by rather wide, straight transverse septa; aperture central, mammillate.

Length, 2.4 mm.

Locality.—Rancocas formation, New Egypt, New Jersey.

Geological distribution.—Cretaceous to Recent.

Dr. Anthony Woodward describes this species from Stratton's marl pit, near Mullica Hill, where it occurs in the shell layer of the green marl, and also from Timber Creek, in the lime-sand bed; but it is not a common form in either locality.

Digitized by Google

NODOSARIA WILLIAMSI Bagg.

Plate III, figs. 2a, 2b.

Nodosaria williamsi Bagg, 1895; Johns Hopkins Univ. Circulars, No. 121, October, 1895, No. 59.

Test small, oval or elliptical, similar to *Nodosaria comata* Batsch, but differing from that species in the arrangement of the costæ, which in our specimens extend the entire length of the shell, while in the former species the oral end is smooth. The costæ are very numerous, fine; chambers three or four, large, inflated, scarcely discernible by the transverse septa; unconstricted at the septal nodes; ultimate chamber truncate; aperture very large, rotund.

Length, 1.13 mm.

Locality.—Rancocas formation, southeast Swedesboro, New Jersey. Rare.

Geological distribution.—Upper Cretaceous.

NODOSARIA ZIPPEI Reuss.

Plate III, fig. 1 (aberrant form).

Nodosaria zippei Reuss, 1844; Geogn. Skizze Böhm, Vol. II, pt. 1, p. 210.

Nodosaria zippei Reuss, 1845–[illegible]; Verstein. böhm. Kreide, pt. 1, p. 25, Pl. VIII, figs. 1–3.

Dentalina pulchra Gabb, 1860; Jour. Acad. Nat. Sci., Philadelphia, n. s., Vol. IV, p. 402, Pl. LXIX, figs. 40, 41.

Nodosaria raphanistrum Woodward, 1894; Jour. N.Y. Microsc. Soc., Vol. X, No. 4, p. 110.

Test straight, or but slightly arcuate, very large and long, sometimes reaching 10 millimeters in length; chambers numerous, becoming more distinct toward the ultimate chamber; primordial segment slightly larger than the one succeeding, mucronate; surface of shell marked by from seven to fourteen (usually about twelve) very prominent costæ, only part of which extend the whole length of the shell; ultimate chamber slightly prolonged; aperture rotund.

Length, 9 mm. and over. Small specimens, 3.2 mm.; breadth, 0.5–1 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Monmouth formation, Freehold, New Jersey; Rancocas formation, Blue Ball, Vincentown, Harrisonville, etc., New Jersey; Manasquan formation, Vincentown, New Jersey.

This beautiful species is one of the very largest forms of Foraminifera found in the New Jersey Cretaceous marl beds, and was described by Gabb as early as 1860, under the name *Dentalina pulchra.* Owing to its great length it is very easily broken, so that only a few of the largest specimens are perfect. It was very well described by Reuss in 1844 (loc. cit.), who said that its length was sometimes 1½ inches, the number of chambers twenty to thirty, the costæ seven to fourteen, and that there were secondary riblets occasionally set in between the main costæ and running a short distance along the surface of the shell.

Digitized by Google

Reuss also pointed out the similarity of *Nodosaria septemcostata* and *N. undecimcostata* Geinitz, and considered the two latter as identical with *N. zippei*. Dr. Anthony Woodward considers this species identical with *N. raphanistrum*, but the two species are sufficiently distinct to justify the retention of the original name given by Professor Reuss.

This species has a very wide geological range and distribution in the Cretaceous, and occurs in every marl bed of New Jersey.

In the large amount of material examined in the preparation of this report an interesting case of dimorphism was observed in one of the specimens of *Nodosaria zippei*. The shell which has been previously referred to begins as a textularian with two chambers side by side, each bearing the same number of costæ as the original form and united above into a straight typical nodosarian chamber. It was found in the green marl of Blue Ball, where the Nodosariæ are so perfectly preserved that mucronate forms still retain their spines in almost perfect condition.

Genus LINGULINA d'Orbigny.

LINGULINA CARINATA d'Orbigny.

Lingulina carinata d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 257, No. 1.
Lingulina carinata Brady, 1884; Chal. Rept., Vol. IX, p. 517, Pl. LXV, fig. 16, 17.

Test elliptical, elongate, laterally compressed; surface smooth and glistening; shell consisting of six somewhat extended chambers, separated by arched septa; peripheral margin obtusely angular; chambers increasing rapidly in size toward the distal end and marked by distinct transverse septal lines; primordial chamber circular, not elevated; aperture a narrow terminal slit.

Length, 1.2–1.85 mm.; breadth, 1–1.3 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This beautiful little species is common in the lime sand at Vincentown. It resembles *Lingulina bohemica* Reuss both in its lateral compression and in its external form, but is distinguished from that form by its broader elliptical outline and in having invariably six chambers instead of five.

Genus FRONDICULARIA Defrance.

FRONDICULARIA ALATA d'Orbigny.

Plate II, fig. 4b (bottom form).

Frondicularia alata d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 256, No. 2.
Frondicularia alata Brady, 1884; Chal. Rept., Vol. IX, p. 522, Pl. LXV, figs. 20–23; Pl. LXVI, figs. 3–5.

Test broadly oval, large, complanate; surface smooth, marked by fairly distinct septal lines; chambers narrow, numerous, arched; pri-

Digitized by Google

mordial segment oval, elevated, situated a little within the periphery; basal portion of shell more or less covered by spinous projections, which are either single or united.

Length, 4.34 mm.; breadth, 3 mm.

Locality.—Rancocas formation, Vincentown, Brownsville, etc., New Jersey.

Geological distribution.—Cretaceous to Recent.

This form is rather common in many localities where the lime sand is developed.

FRONDICULARIA ANGUSTA (Nilsson) var. DIMIDIA Bagg.

Plate III, figs. 7a, 7b.

Planularia angusta Nilsson, 1827; Petref. Suec. p. 11, Pl. IX, fig. 22 a, A.

Frondicularia angusta Reuss, 1845–46; Verstein, böhm. Kreide, pt. 1, p. 29, Pl. VIII, figs. 13, 14.

Test lanceolate, very elongate, strongly compressed and leaf-like; consisting of from ten to twelve chambers, which gradually increase in size toward the proximal end, where the greatest breadth occurs; primordial chamber spherical, elevated, mucronate, and the surface marked by three sharply defined ribs; surface of shell marked by numerous fine longitudinal lines, running nearly parallel to the lateral edges; septa distinct, slightly raised externally as ridges; aperture normally round, terminal.

Length, 2.6 mm.; breadth, 1 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous.

This species is very closely allied to the European form, but differs principally in the number of chambers, which is invariably less than one-half of those of the former type. It is common in the lime sand at Vincentown.

FRONDICULARIA ARCHIACIANA d'Orbigny, var. STRIGILLATA, nov. var.

Plate III, fig. 5.

Frondicularia archiaciana d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 20, Pl. I, figs. 34–36.

Frondicularia archiaciana Brady, 1884; Chal. Rept., Vol. IX, p. 520, Pl. CXIV, fig. 12.

Test elongate, complanate, anteriorly acute, posteriorly obtuse, and provided with a short spine; chambers, six to eight, relatively large, equally compressed, and slightly limbate at the lateral edges; surface marked by definite elevated striæ, of which the two central rows are more prominent than those near the margin; primordial chamber globular; ultimate chamber prolonged, tube-like; aperture small, rotund.

Length, 1.6 mm.; breadth, 0.6 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

Digitized by Google

FRONDICULARIA CLARKI Bagg.

Plate III, fig. 4.

Frondicularia clarki Bagg, 1895; Johns Hopkins Univ. Circulars No. 121, October.

Test complanate, smooth, very elongate oval in outline; consisting of from twelve to fourteen narrow parallel chambers; primordial chamber bulbous, elevated, costate, mucronate; ultimate chamber elongate, bearing upon one surface a hollow, somewhat extended tube, which forms an elevated median ridge with rather angular edges, and extends for a short distance down the shell. This tube terminates anteriorly in the nearly rotund aperture.

Length, 3.4 mm.; breadth, 0.9 mm.

Locality.—Monmouth formation, Atlantic Highlands, New Jersey. Very rare.

Geological distribution.—Cretaceous.

I have named this interesting species after my friend and instructor, Prof. William B. Clark.

FRONDICULARIA GAULTINA Reuss.

Frondicularia gaultina Reuss, 1860; Sitz. Akad. Wiss. Wien, Vol. XL, p. 194, Pl. V, fig. 5.

Test rather narrow, smooth, very elongate, compressed; consisting of numerous chambers, gradually increasing in size from below upward; septal lines approximately straight, paralleled, depressed; shell broadest nearer the ultimate segment, gradually diminishing below; primordial segment not preserved.

Length unknown.

Locality.—Matawan formation, Marshalltown, New Jersey. Rare.

Geological distribution.—Cretaceous.

FRONDICULARIA INVERSA Reuss.

Frondicularia inversa Reuss, 1844; Geogn. Skizze Böhm., Vol. II, pt. 1, p. 211.
Frondicularia inversa Reuss, 1845–46; Verstein. böhm Kreide, pt. 1, p. 31, Pl. VIII, figs. 15–19; Pl. XIII, fig. 42.

Test complanate, leaf-like, elongate, smooth, broadest near the middle, tapering at the sides toward the anterior and posterior ends by straight wedge-shaped lateral margins; peripheral edges square; one lateral surface slightly curved along the median line, opposite surface approximately flat; chambers ten to twelve, narrow, elongate, nearly parallel to upper peripheral edges; primordial chamber oval, elevated, marked by a median ridge, mucronate; aperture rotund, crenulated.

Length, 2.82 mm.; breadth, 1 mm.

Locality.—Monmouth formation, Freehold, New Jersey. Rare.

Geological distribution.—Cretaceous.

Digitized by Google

FRONDICULARIA LANCEOLA Reuss.

Frondicularia lanceola Reuss, 1865; Reuss's Model No. 23 (Catalogue No. 46, 1851).

Test very elongate, lanceolate, tapering sharply to an acute point at the primordial end; segments numerous, twelve or more, quadrangular in cross section; septa depressed sharply, so that the chambers appear elevated into oblique folds; surface smooth and glistening; peripheral margin limbate; ultimate chamber extended into a distinct tube, which carries the oral aperture; primordial chamber nearly circular, not elevated; aperture radiate.

Length, 3 mm.; breadth, 0.6 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

I have only one specimen of this beautiful form.

FRONDICULARIA MAJOR Bornemann.

Plate III, fig. 3.

Frondicularia major Bornemann, 1854; Liasform, Göttingen, p. 36, Pl. III, figs. 21 a–c.

Test smooth, compressed, somewhat thicker along the median line, thinner at the peripheral margins, which are neatly rounded; chambers varying from four to nine; somewhat convex forward; septal lines distinct; posterior margin obtusely rounded; anterior acuminate; aperture a central radiate opening.

Length, 1–4 mm.; breadth, 1.6 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Lias to Cretaceous.

FRONDICULARIA OVATA Roemer.

Plate II, figs. 4a, 5b (bottom forms), and Plate IV, figs. 2a, 2b.

Frondicularia ovata Roemer, 1840; Verstein, norddeutsch. Kreid., p. 96, Pl. XV, fig. 9.

Test ovate, complanate, smooth; consisting of a small number of parallel chambers, which are distinct and marked very slightly at the lower peripheral edges by the septal endings; primordial chamber flat, basal; ultimate chamber large, slightly prolonged into the rounded aperture; peripheral margins rather squarely set off.

Length, 9.82 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous.

FRONDICULARIA PULCHELLA Karrer.

Frondicularia pulchella Karrer, 1870; Jahrb. k. k. geol. Reichsanstalt, Vol. XX, p. 171, Pl. 1, fig. 8.

Test large, elongated, complanate; surface smooth, marked by rather

Digitized by Google

distinct septal lines, which separate the narrow, extended, parallel chambers; greatest width near the middle of the shell, thence tapering rather sharply toward both extremities, but the lower portion slightly incurved, while the anterior end is slightly outcurved, though not markedly so; primordial segment lost.

Length, about 5 mm.; breadth (central), 1.8 mm.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous.

FRONDICULARIA RETICULATA (Reuss).

Plate III, fig. 6.

Flabellina reticulata Reuss, 1850; Haidinger's Nat. Abhandl., Vol. IV, pt. 1, p. 30, Pl. I, fig. 22.

Test thin, leaf-like, broad at the center, but tapering rapidly toward the oral end; consisting of ten rather narrow, elongated chambers, the surfaces of which are marked transversely by numerous delicate costæ, which run from septum to septum, and completely cover the whole form like a network; primordial chamber nearly circular, but not elevated, very slightly eccentric, yet not enough to justify its being placed among flabelline types.

Length, 0.87 mm.; greatest breadth, 0.88 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

This is one of the most beautiful of all frondicularians, and is at the same time exceedingly rare. We have only one specimen from the Lower Marl at Freehold, and it is interesting to note that Professor Reuss records the single occurrence of a perfect specimen from the Kreidemergel of Lemberg.

FRONDICULARIA VERNEUILINA d'Orbigny.

Frondicularia verneuilina d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 20, Pl. I., figs. 32, 33.

Test elongate elliptical; peripheral margins gracefully curved, broadest near the center, not compressed laterally as much as most Frondicularia; chambers relatively large, few; primordial segment globose, costate, mucronate, distinctly set off from the succeeding chamber; ultimate chamber prolonged into a tubular neck, which carries the little round aperture.

Length, 1.5 mm.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous.

Digitized by Google

Genus RHABDOGONIUM Reuss.

RHABDOGONIUM ROEMERI Reuss.

Rhabdogonium roemeri Reuss, 1860; Sitz. Akad. Wiss. Wien., Vol. XL, p. 201, Pl. VI, fig. 7.

Test coarsely arenaceous, partly composed of glauconite grains, elongate, straight, or slightly bent, sharply triangular, obtusely rounded and slightly angular at the ends; peripheral margin curved, sharp; chambers few in number, usually six, short, separated by arched depressed septa; aperture elliptical, placed centrally at the distal end.

Length, 1.5 mm.

Locality.—Matawan formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

RHABDOGONIUM TRICARINATUM (d'Orbigny).

Vaginulina tricarinata d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 258, No. 4; Modèle, No. 4.

Rhabdogonium pyramidale Karrer, 1861; Sitz. Akad. Wiss. Wien, Vol. XVI, p. 19, Pl. I, fig. 34.

Rhabdogonium tricarinatum Brady, 1884; Chal. Rept., Vol. IX, p. 525, Pl. LXVII, figs. 1–3.

Test triangular, elongated and gradually tapering toward both extremities; peripheral margins sharp, becoming slightly twisted below; anterior end prolonged into a tube-like neck; chambers about ten, narrow, arched, and separated by curved septa; aperture rotund.

Length, 2.6 mm.

Locality.—Rancocas formation, Brownsville, New Jersey.

Geological distribution.—Cretaceous to Recent.

RHABDOGONIUM TRICARINATUM var. ACUTANGULUM Reuss.

Rhabdogonium tricarinatum var. *acutangulum* Reuss, 1862 (1863); Sitz. Akad. Wiss. Wien, Vol. XLVI, Abth. 1, p. 55, Pl. IV, fig. 14, a, b.

Test small, trihedral, coarsely arenaceous; the three marginal angles sharp and distinct; chambers few, short, separated by somewhat arched septa, not very distinct externally; primordial end sharp, anterior obtusely angular; aperture triangular, with incurved lateral edges.

Length, 1.73 mm.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous.

Genus MARGINULINA d'Orbigny.

MARGINULINA ENSIS Reuss.

Marginulina ensis Reuss, 1845–46; Verstein. böhm. Kreide, pt. 1, p. 29, Pl. XII, fig. 13; Pl. XIII, figs. 26, 27; pt. 2, p. 106, Pl. XXIV, fig. 30.

Nodosaria communis Woodward, 1894; Jour. N. Y. Microsc. Soc., Vol. X, No. 4, p. 103.

Test elongate, moderately compressed, oval or elliptical in trans-

Digitized by Google

verse section; shell variable in outline, either nearly straight throughout its whole length or incurved; septa very slightly oblique, directed toward the primordial chamber, apparent externally as ridges; proximal chambers more involute than in *Marginulina elongata;* chambers numerous, apparent externally; ultimate chamber somewhat prolonged, and ending posteriorly in a short tube; aperture rotund, with crenulated margin.

Length.—1.3, 1.73 mm.; breadth, 0.43 mm.

Locality.—Monmouth formation, Bruere's pits on Crosswicks Creek; Rancocas formation, Blue Ball, Mullica Hill, New Egypt, New Jersey.

Geological distribution.—Cretaceous.

Professor Sherborn prefers to change the word Marginulina to Cristellaria for this species, thus making it *Cristellaria ensis* (Reuss). The writer prefers to leave it under the original name of Professor Reuss.

MARGINULINA PEDIFORMIS Bornemann.

Marginulina pediformis Bornemann, 1855; Zeitsch. d. geol. Gesell., Vol. VII, p. 326, Pl. XIII, fig. 13.

Marginulina pedum d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 68, Pl. III, figs. 13, 14.

Test smooth, short, circular in transverse section; consisting of about six chambers, of which the first two or three are inrolled and rounded at the base; segments becoming more definite above; ultimate chamber largest and slightly prolonged; aperture small, rotund, crenulate; septa depressed, slightly oblique, though not markedly so.

Length, 1 mm.

Locality.—Matawan formation, Marshalltown, New Jersey.

Geological distribution.—Cretaceous, Tertiary.

MARGINULINA TRILOBATA d'Orbigny.

Marginulina trilobata d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 16, Pl. I, figs. 16, 17.

Test elongate, smooth, and glistening, compressed laterally, slightly arcuate at the primordial end; somewhat tapering; chambers short, oval, regular, numerous, ten to sixteen, slightly constricted; surface marked by small, distinct, elliptical ridges, giving the form a peculiar trilobed appearance, whence its name; primordial chamber small, nearly spherical; septal lines depressed; aperture small, radiate.

Length, 4 mm. in large specimens; breadth, 0.6 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

Digitized by Google

Genus VAGINULINA d'Orbigny.

VAGINULINA LEGUMEN (Linné).

Plate IV, fig. 4.

Nautilus legumen Linné, 1758; Syst. Nat., tenth ed., p. 711, No. 248; 1767, twelfth ed., p. 1164, No. 288.

Vaginulina legumen Terrigi, 1891; Memoire R. Com. g. Regno, Vol. IV, pt. 1, p. 94, Pl. III, fig. 6.

Test straight or nearly so, smooth, compressed laterally, pod-like; consisting of only six or seven chambers; septa nonlimbate, oblique, parallel, not very distinct externally; ultimate chamber slightly prolonged upon one side and carrying the small radiate aperture.

Length, 1.3 mm; breadth, 0.47 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Rancocas formation, Vincentown, New Egypt, Mullica Hill, New Jersey.

Geological distribution.—Trias to Recent.

The above species has been lately described from the Alabama chalk by Dr. Woodward. It is a beautiful little shell, of snow-white color, and is rather rare.

VAGINULINA STRIGILLATA Reuss.

Plate IV, fig. 3.

Citharina strigillata Reuss, 1845–46; Verstein. böhm. Kreide, pt. 2, p. 106, Pl. XXIV, fig. 29.

Vaginulina strigillata and var. Jones and Parker, 1860; Quart. Jour. Geol. Soc., Vol. XVI, Pl. XX, figs. 29–35.

Test complanate, leaf-like, very large, roughly triangular; surface smooth, marked by slightly elevated septal lines; chambers numerous, often as many as twenty-five, narrow, parallel, slightly oblique, becoming constricted toward the curved margin and passing rapidly downward toward the proximal end, where the septal lines finally appear only as fine ridges. As a result of this constriction of the chambers at the curved margin, transverse sections show only four or five chambers. Along the straight edge run three elevated, rounded costæ, with sometimes one or two smaller ones between. The latter, however, do not extend the whole length of the shell as do the ridges. Septal lines distinct, slightly crenate, becoming much thickened toward the straight edge of the shell; primordial chamber oval, elevated, slightly mucronate, covered by numerous costæ.

Length, 3–9 mm; breadth, 2.3 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

This species is very common in the lower marl of Freehold, but I have not found it elsewhere.

Digitized by Google

CRISTELLARIA Lamarck.

CRISTELLARIA ACUTAURICULARIS (Fichtel and Moll).

Nautilus acutauricularis Fichtel and Moll, 1803; Test. Micros., p. 102, Pl. XVIII; figs. *g–i*.

Cristellaria navicula d'Orbigny, 1840; Mém. Soc. géol. France, Vol. IV, ser. 1, p. 27, Pl. II, figs. 19, 20.

Cristellaria acutauricularis Brady, 1884; Chal. Rept., Vol. IX, p. 543, Pl. CXIV, fig. 17 *a*, *b*.

Test involute, thick, convex, smooth; septal plane broad, triangular, nearly flat; chambers seven or eight, weakly curved; keel acute carinate; aperture nipple-shaped, situated at the extremity of the convex side.

Length, 1.43 mm.; breadth, 0.65 mm.

Locality.—Rancocas formation, Timber Creek, Vincentown, New Jersey.

Geological distribution.—Lias (?), Cretaceous to Recent.

CRISTELLARIA ARTICULATA (Reuss).

Robulina articulata Reuss, 1863; Sitz. Akad. Wiss. Wien, Vol. XLVIII, p. 53, Pl. V, fig. 62.

Cristellaria articulata Brady, 1884; Chal. Rept., Vol. IX, p. 547, Pl. LXIX, figs. 10–12, also 1–4.

Test nearly circular, smooth, thickened, flattened at the sides; obtusely angular peripheral margin; chambers six or seven, broadly triangular, separated by depressed septa; aperture oval, surrounded by a fissured border.

Diameter, 1.3 mm.

Locality.—Rancocas formation, Vincentown, Mullica Hill, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

Professor Brady considers this species a thick variety of *Cristellaria rotulata*.

CRISTELLARIA CASSIS (Fichtel and Moll).

Nautilus cassis Fichtel and Moll, 1798; Test. Micros., p. 95, var. *α*, Pl. XVII, fig. *a–d*; var. *β*, Pl. XVII, fig. *e–g*; var. *γ*, Pl. XVII, figs. *h–i*; var. *δ*, Pl. XVII, figs. *k*, *l*; var. *ε*, Pl. XVIII, figs. *a–c*.

Cristellaria cassis Brady, 1884; Chal. Rept., Vol. IX, p. 552, Pl. LXVIII, fig. 10.

Test very large, complanate, elongate oval, distinctly carinate; chambers irregular, ten to fifteen in final volution; septa distinct, arcuate, depressed; aperture oval with crenulated margin.

Length, 4.3–4.56 mm.; breadth, 3–4 mm.

Locality.—Rancocas formation, Vincentown, Brownsville, New Egypt, etc., New Jersey.

Geological distribution.—Cretaceous to Recent.

Digitized by Google

CRISTELLARIA CREPIDULA (Fichtel and Moll).

Nautilus crepidula Fichtel and Moll, 1803; Test Micros., p. 107, Pl. XIX, figs. *g–i*.
Cristellaria crepidula d'Orbigny, 1839; Foram. Cuba, p. 64, Pl. VIII, figs. 17, 18.

Test elongate, arcuate, smooth, compressed, pellucid; chambers ten to twelve, oblique, separated by slightly convex walls; posterior chambers involute, anterior chambers evolute; aperture rotund, slightly crenate.

Length, 0.7 mm; breadth, 0.26 mm.

Locality.—Rancocas formation, Vincentown, Mullica Hill, New Jersey.

Geological distribution.—Lias to Recent.

The above form is not a common species. Our specimens are similar in shape to *Cristellaria intermedia* Reuss, which is considered as identical with the above by Professor Brady.

CRISTELLARIA CRETACEA Bagg.

Plate V, figs. 2a, 2b.

Test complanate, smooth, elongate, oval, resembling *Cristellaria cassis* in general contour, but differing from that species in the absence of the marginal keel; margin rounded; chambers numerous, about twelve in final convolution, narrow, elongated; septa distinct, convex; ultimate chamber truncate, anterior margin straight; aperture small, narrow elliptical, with crenulated margin.

Length, 4.3 mm.; breadth, 3 mm.

Locality.—Rancocas formation, Vincentown, New Jersey. Common.

Geological distribution.—Cretaceous.

The above species is less elongated than *Cristellaria projecta*, which it resembles closely.

These two forms, together with *Cristellaria cassis*, are rather abundant at Vincentown, and all attain an enormous size for the type.

CRISTELLARIA CULTRATA (Montfort).

Plate VI, fig. 1.

Robulus cultratus Montfort, 1808; Conch. Syst., Vol. I, p. 214, 54e genre.
Robulina cultrata d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 96, Pl. IV, figs. 10–13.

Test circular, biconvex, smooth and glistening, peripheral margin sharp, broadly keeled; chambers seven to eleven, in final convolution, somewhat convex, smooth or costate; aperture radiate.

Diameter, 1–2 mm.

Locality.—Monmouth formation, Freehold, Bruere's pits, on Crosswicks Creek, Marlboro, New Jersey; Rancocas formation, Mullica Hill, New Egypt, Swedesboro, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

Digitized by Google

This species is common at Freehold and is beautifully preserved. The width of the marginal keel is variable, as is also the number of chambers. It is similar to *Cristellaria rotulata*, with the addition of the keel. Specimens of *Cristellaria cultrata* from New Egypt and Swedesboro are not smooth, as in typical forms, but are marked externally by raised septa.

CRISTELLARIA GIBBA d'Orbigny.

Cristellaria gibba d'Orbigny, 1839; Foram. Cuba, p. 63, Pl. VII, figs. 20, 21.

Test oblong, biconvex, smooth, subcarinate, narrow; chambers few (seven or eight), slightly arcuate, separated by distinct septa; aperture marginate.

Length, 1.3 mm.; breadth, 0.87 mm.

Locality.—Rancocas formation, Vincentown, Mullica Hill, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

CRISTELLARIA ITALICA (Defrance).

Plate IV, figs. 5a, 5b.

Sarecenaria italica Defrance, 1824; Dict. Sci. Nat., Vol. XXXII, p. 177; Vol. XLVII, p. 344; Atlas Conch., Pl. XIII, fig. 6.

Cristellaria italica, Brady, 1884; Chal. Rept., Vol. IX, p. 544, Pl. LXVIII, figs. 17, 18, 20–23.

Test elongate, trihedral, planospiral segments few, succeeding chambers five or six, arranged in a nearly straight superimposed series; dorsal margin sharp, noncarinate; transverse section triangular, segments short, slightly oblique, inclined anteriorly toward initial end.

Length, 1 mm.

Locality.—Rancocas formation, Swedesboro, Blue Ball, Mullica Hill, New Jersey.

Geological distribution.—Cretaceous to Recent.

This is not a common species. It bears some resemblance to *Cristellaria acutauricularis*, but is more elongate, and the anterior edge is more erect. Another species, closely allied to the above form, is *Marginulina triangularis* d'Orbigny.[1]

CRISTELLARIA MAMILLIGERA Karrer.

Cristellaria mamilligera Karrer, 1864; Novara Exped. Geol., Vol. I, pt. 2, p. 76, Pl. XVI, fig. 5.

Cristellaria mamilligera Brady, 1884; Chal. Rept., Vol. IX, p. 553, Pl. LXX, figs. 17, 18.

Test complanate, nearly circular; anterior margin truncate, posterior margin slightly carinate; surface ornamented with a number of large raised ridges and tubercles in the umbilical region; septa depressed, the depressions partially filled by exogenous material which forms the

[1] Foram. Foss. Bassin tert. Vienne, 1846, p. 71, Pl. III, figs. 22, 23.

Digitized by Google

ridges; chambers large, slightly arcuate, eight or nine in the final convolution; septal plane narrow, surrounded by a definite border; aperture an elongate-oval opening surrounded by a crenulated margin.

Diameter, 1.74 mm.

Locality.—Rancocas formation, Blue Ball, New Jersey.

Geological distribution.—Cretaceous to Recent.

This species is very rare in the green marl of Blue Ball, and has not been recognized elsewhere.

CRISTELLARIA MEGAPOLITANA Reuss.

Robulina megapolitana Reuss, 1855; Zeits. d. geol. Gesell., Vol. VII, p. 272, Pl. IX, fig. 5.

Test circular, compressed, smooth and glistening, keeled and with more or less definite flange. There are seven or eight strongly curved chambers apparent externally as raised lines, which are thicker at the umbilicus, but become attenuated toward the peripheral margin. Umbilical disk more or less distinct. Septal plane triangular, with raised border.

Length, 1–1.5 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

CRISTELLARIA PROJECTA Bagg.

Plate V, figs. 1a, 1b.

Cristellaria projecta Bagg, 1895; Johns Hopkins Univ. Circulars, No. 121, October, 1895.

Test greatly elongated, complanate, smooth, consisting of two and one-half convolutions; chambers numerous, twenty or more in the last volution, arcuate, narrow, elongate; ultimate chamber nearly at right angles to umbilicus; margin rounded; septal lines very slightly depressed; aperture elliptical.

Length, 5.3 mm.; breadth, 2.7 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous.

This is a rare form in the lime sand at Vincentown, and has not been found elsewhere.

CRISTELLARIA ROTULATA (Lamarck).

Lenticulites rotulata Lamarck, 1804; Annales du Mus., Vol. V, p. 188, No. 3.
Cristellaria rotulata d'Orbigny, ser. 1, 1840; Mém. Soc. géol. France, Vol. IV, p. 26, Pl. II, figs. 15–18.

Test involute, biconvex, smooth; peripheral edge sharp, noncarinate; chambers numerous, but only eight or nine in final solution; septa moderately curved, visible externally as fine lines; aperture elliptical, radiate.

Digitized by Google

Diameter, 1–2 mm.

Locality.—Rancocas formation, Vincentown, Blue Ball, New Egypt, Mullica Hill, Timber Creek, etc., New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Triassic to Recent.

This is one of the most common forms in the lime-sand bed, and is especially plentiful at Vincentown. The size of the shell is very variable, some of the largest specimens being more than 2 millimeters in diameter.

CRISTELLARIA SECANS Reuss.

Cristellaria secans Reuss, 1859 (1860); Sitz. Akad. Wiss. Wien, Vol. XL, p. 214, Pl. IX, fig. 7.

Test circular, laterally compressed, sharply keeled on the peripheral margin; umbilical disc prominent and septa radiating from this in gently curving lines; about ten small triangular chambers in the last convolution.

Diameter, 1.5 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

CRISTELLARIA TRACHYOMPHALA (Reuss).

Robulina trachyomphala Reuss, 1850; Haidinger's Nat. Abhandl., Vol. IV, pt. 1, p. 34, Pl. III (error for II), fig. 12.

Test rounded, compressed, with angular periphery; umbilical disc raised, nearly round, more marked in some forms than in others; septal lines distinct, convex. There are from eight to ten chambers in the last whorl. Aperture a triangular-shaped opening surrounded by a raised crenulated margin at the external edge of the ultimate segment.

Diameter, 0.86–1.3 mm.

Locality.—Rancocas formation, Blue Ball, New Jersey.

Geological distribution.—Cretaceous.

CRISTELLARIA TRIANGULARIS d'Orbigny.

Cristellaria triangularis d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 27, Pl. II, figs. 21, 22.

Cristellaria triangularis Reuss, 1845–46; Verstein. böhm. Kreide, pt. 1, p. 34, Pl. VIII, fig. 48.

Test triangular, very convex, smooth; periphery sharply carinate; lateral surfaces somewhat concave; chambers few, six or seven, large, evolute, superposed; septa oblique, very slightly convex anteriorly; septal plane broadly triangular; aperture radiate.

Length, 1 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Digitized by Google

Geological distribution.—Cretaceous.

The occurrence of this species from the craie blanche of the Paris basin, France, was recorded by d'Orbigny as early as 1840. I have found but two specimens in the lower marl of Freehold.

CRISTELLARIA WETHERELLII (Jones).

Marginulina wetherellii Jones, 1854; Morris Catalogue, Brit. Foss., ed. 2, p. 37.
Cristellaria wetherellii Brady, 1884; Chal. Rept., Vol. IX, p. 537, Pl. CXIV, fig. 14.

Test elongate, pod-like, compressed; primordial segments spiral, ultimate segments straight, evolute; surface marked by large tubercles more or less regular and crossing the shell surface like septal ridges; aperture round, at the end of a somewhat prolonged neck.

Length, 1.56 mm.; breadth, 0.5 mm.

Locality.—Rancocas formation, Vincentown, Mullica Hill, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

The above species is rare at Vincentown. Dr. Woodward states that it is rare at Mullica Hill, but common at Timber Creek.

Genus FLABELLINA d'Orbigny.

FLABELLINA CORDATA Reuss.

Flabellina cordata Reuss; Verstein. böhm. Kreide, pt. 1, p. 32, Pl. VIII, figs. 37–46, 78.
Flabellina cordata Reuss, 1854; Denks. Akad. Wiss. Wien, Vol. VII, p. 67, Pl. XXV, figs. 6–8.

Test broadly ovate or heart-shaped, complanate, with numerous narrow, elongated chambers; primordial chamber somewhat elevated and more or less globular, succeeding chambers at first flabelline, later Frondicularia-like; anterior extremity wedge-like with gently curving sides, posterior border much wider than in *Flabellina sagittaria* and differing from that species in the irregularity of the basal margin caused by the extension of the primordial chamber; surface of test smooth and glistening; aperture a small radiate, terminal opening.

Length, 1.8–4 mm.

Locality.—Rancocas formation, Vincentown, Brownsville, New Jersey.

Geological distribution.—Cretaceous.

FLABELLINA SAGITTARIA (Lea).

Plate IV, figs. 1a, 1b.

Palmula sagittaria Lea, 1833; Contributions to Geol., pp. 219–220, Pl. VI, fig. 228.
Planularia cuneata Morton, 1842; Jour. Acad. Nat. Sci., Philadelphia, Vol. VIII, pt. 2, p. 214, Pl. XI, fig. 5.

Test complanate, broadly elliptical (sometimes rather narrow and more elongate), occasionally slightly convex along the median line, while the opposite side is concave, though in typical specimens both surfaces are flat; septa distinct, forming a sharp median angle;

Digitized by Google

chambers numerous, the number dependent somewhat upon the size of the individual; peripheral margins moderately rounded; primordial chamber bulbous, mucronate, or more usually smooth; surface smooth and glistening; aperture typically mammillate, though frequently the shell is worn or broken off so that a round opening appears.

Length, 1–9 mm.; breadth, 1–4.3 mm.

Locality.—Rancocas formation, Vincentown, Blue Ball, New Egypt, Brownsville, etc., New Jersey.

Geological distribution.—Cretaceous.

This species is one of the most common forms at Vincentown. It is very variable in size and shape and is found in all stages of growth. As has been previously stated, it was the first Foraminifera to be described from the New Jersey greensands. (Lea, loc. cit.)

Subfamily POLYMORPHININÆ.

Genus POLYMORPHINA d'Orbigny.

POLYMORPHINA COMPRESSA d'Orbigny.

Polymorphina compressa d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 233, Pl. XII, figs. 32–34.

Test oblong, compressed, inequilateral; chambers numerous, arranged biserially, somewhat inflated; septal lines depressed, surface smooth; aperture variable, usually simple, circular, and coronate, sometimes labyrinthic or porous.

Length, 3 mm. in large specimens.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Lias to Recent.

POLYMORPHINA COMMUNIS (d'Orbigny).

Plate VI, fig. 2.

Guttulina communis d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 266, Pl. XII, figs. 1–4; Modèles, No. 62.

Polymorphina communis, Brady, Parker, and Jones, 1870; Trans. Linn. Soc., London, Vol. XXVII, p. 224, Pl. XXXIX, fig. 10 a b.

Test irregularly ovoidal, or egg-shaped, consisting of about four visible segments; anterior extremity acute; posterior obtuse; surface smooth, with distinct septal depressions; chambers inflated, elliptical, embracing; aperture mammillate.

Length, 1.3–1.4 mm.; breadth, 1–1.3 mm.

Locality.—Rancocas formation, Vincentown, New Jersey. Common.

Geological distribution.—Lias to Recent.

POLYMORPHINA EMERSONI n. sp.

Plate VI, fig. 3.

Test elongate oval, oval end acute, posterior obtusely rounded; surface of test covered completely by fine longitudinal costæ; chambers

Digitized by Google

two, elongated, oblique, separated by nearly straight septa slightly marked near the posterior end and depressed at the peripheral margin; aperture rotund.

Length, 1.9 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

This is a very rare species, and has only been obtained in the lower marl of Freehold. I have named it after Prof. B. K. Emerson.

POLYMORPHINA GIBBA (d'Orbigny).

Globulina gibba d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 266, No. 20; Modèle No. 63.

Polymorphina gibba Brady, Parker, and Jones, 1870; Trans. Linn. Soc. London, Vol. XXVII, p. 216, Pl. XXXIX, fig 2 a–d.

Test subglobular, apex slightly produced, base obtusely rounded; consisting of from two to four chambers, compactly joined and overlapping; surface smooth, unmarked by septal constrictions; septa visible as delicate, oblique lines, laterally very slightly compressed, though usually nearly circular in transverse section; shell larger than *Polymorphina lactea*, less elongated toward the apex; aperture mammillate.

Diameter, 0.5–1.17 mm.

Locality.—Monmouth formation, Freehold, New Jersey; Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Jurassic to Recent.

POLYMORPHINA LACTEA (Walker and Jacob).

Serpula lactea Walker and Jacob, 1798 (fide Kanmacher); Adams's Essays, second ed., p. 634, Pl. XXIV, fig. 4.

Polymorphina lactea Brady, 1884; Chal. Rept., Vol. IX, p. 559, Pl. LXXI, fig 11 (typical), Pl. LXXII, fig. 14 (variety).

Test ovate or subpyriform, only slightly compressed; three or four chambers, scarcely visible externally; aperture terminal, radiate.

Diameter, 0.87 mm.

Locality.—Monmouth formation, Freehold, New Jersey; Rancocas formation, Vincentown, Blue Ball, New Egypt, Timber Creek, etc., New Jersey.

Geological distribution.—Jurassic to Recent.

POLYMORPHINA LACTEA elongate variety Brady.

Polymorphina lactea elongate variety Brady, 1884; Chal. Rept., Vol. IX, p. 559, Pl. LXXI, fig. 14.

Test similar to the preceding, but elongated.

Length, 1.5 mm.; breadth, 0.6 mm.

Digitized by Google

Locality.—Rancocas formation, Vincentown, New Jersey.
Geological distribution.—Similar to that of preceding form.

POLYMORPHINA OBLONGA d'Orbigny.

Polymorphina oblonga d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 232, Pl. XII, figs. 29–31.

Test elongate, consisting of a small number of oblong inflated chambers separated by deep sutures. This feature separates it from *Polymorphina lactea* var. *oblonga* Williamson, which has an oval compressed shell with erect segments and flush sutures.

Length, 1.43 mm.

Locality.—Monmouth formation, Freehold, New Jersey; Rancocas formation, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

POLYMORPHINA ORBIGNII (Zborzewski).

Apiopterina d'orbignii Zborzewski, 1834; Nouv. Mém. Soc. Imp. Nat. Moscou, Vol. III, p. 311, Pl. XXVIII, fig. 2 b.

Polymorphina orbignii Parker, Jones, and Brady, 1870; Trans. Linn. Soc. London, Vol. XXVII, p. 244, Pl. XLII, fig. 38 a–c.

Test oval, with a fistulose base; surface of shell smooth. The tube-like projections are very interesting and peculiar, and are the distinguishing feature of the species. They surround the base like a crown, extend out irregularly, and branch at their distal ends. The figures of this species indicate septal divisions, but these are not discernible externally.

Diameter, 0.87 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous and Tertiary.

POLYMORPHINA PROBLEMA (d'Orbigny).

Guttulina problema d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 266, No. 14, Modèle No. 61.

Polymorphina problema Brady, Parker, and Jones, 1870; Trans. Linn. Soc. London, Vol. XXVII, p. 225, Pl. XXXIX, fig. 11, a-b.

Test oblong ovate, composed of several inflated chambers (six in one specimen) marked by strong septal depressions. Very similar to the more abundant *polymorphina communis*, but differing from that species in the greater number of chambers. Surface of shell smooth; aperture small, rotund, radiate.

Length, 1 mm.; breadth, 0.73 mm.

Locality.—Rancocas formation, New Egypt, Mullica Hill, Timber Creek, New Jersey. Common.

Geological distribution.—Lias to Recent.

Digitized by Google

POLYMORPHINA REGULARIS von Münster.

Polymorphina regularis von Münster, 1838 (fide Roemer); Neues Jahrb. für Min., p. 385, Pl. III, fig. 21.

Polymorphina regularis Brady, Parker, and Jones, 1870; Trans. Linn. Soc. London, Vol. XXVII, p. 229, Pl. XL, fig. 13 a-c.

Test oblong, compressed, biconvex, narrow below but somewhat broader above; peripheral margin thin, rounded; chambers four to nine, oblique; septal lines marked by slight constrictions visible externally; surface smooth; aperture small, round, central, surrounded by fine grooves.

Length, 1–4 mm.; greatest breadth, 1.6 mm.

Locality.—Rancocas formation, Brownsville, New Jersey.

Geological distribution.—Cretaceous and Tertiary.

Family GLOBIGERINIDÆ.

Genus GLOBIGERINA d'Orbigny.

GLOBIGERINA BULLOIDES d'Orbigny.

Globigerina bulloides d'Orbigny, 1826; Ann. Sci. Nat., Vol. VII, p. 277, No. 1, Modèle No. 17 (young) and No. 76.

Globigerina bulloides Brady, 1884; Chal. Rept., Vol. IX, p. 593, Pl. LXXVII, and Pl. LXXIX, figs. 3–7.

"Test spiral, subtrochoid; superior surface convex, inferior more or less convex, but with deeply sunken umbilicus, periphery rounded, lobulated; adult specimens composed of about seven globose segments, of which four form the outer convolution, the apertures of the individual chambers opening independently into the umbilical vestibule. Diameter, sometimes one-fortieth of an inch (0.63 mm.), but oftener much less." (Brady, loc. cit.)

Locality.—Rancocas formation, Vincentown, Swedesboro, New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This species is not uncommon in the lime sand at Vincentown, but it is rather rare in the overlying Manasquan marl beds. It is, however, much larger in the latter, and some specimens measure 0.4 mm. in diameter.

GLOBIGERINA BULLOIDES var. TRILOBA Reuss.

Globigerina triloba Reuss, 1849; Denks. Akad. Wiss. Wien, Vol. I, p. 374, Pl. XLVII, fig. 11, a-c.

Globigerina bulloides var. *triloba* Brady, 1884; Chal. Rept., Vol. IX, p. 595, Pl. LXXIX, figs. 1, 2; Pl. LXXXI, figs. 2, 3.

Test similar to *Globigerina bulloides*, but distinguished from the latter by its consisting of only three visible chambers in the final convolution. The diameter of the shell varies from 0.5 to 1 mm.

Digitized by Google

Locality.—Rancocas and Manasquan formations, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

GLOBIGERINA CRETACEA d'Orbigny.

Globigerina cretacea d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 34, Pl. III, figs. 12–14.

Test rotaliform, but strongly depressed; superior surface flattened or but slightly convex, inferior side depressed toward the center and excavated at the umbilicus; periphery obtuse and lobulated; shell typically composed of three fairly distinct convolutions, the outermost consisting of from five to seven segments, the latter relatively small, subglobular; aperture opening into the umbilical vestibule.

Diameter, less than 1^{mm}.

Locality.—Monmouth formation, Freehold, New Jersey; Rancocas formation, Quinton, Vincentown, Mullica Hill, Timber Creek, etc., New Jersey.

Geological distribution.—Cretaceous to Recent (?).

Family ROTALIDÆ.

Subfamily ROTALINÆ.

Genus DISCORBINA Parker and Jones.

DISCORBINA BERTHELOTI (d'Orbigny).

Rosalina bertheloti d'Orbigny, 1839; Foram. Canar., Vol. II, pt. 2, p. 135, Pl. 1, figs. 28–30.

Discorbina bertheloti, Brady, 1884; Chal. Rept., Vol. IX, p. 650, Pl. LXXXIX, figs. 10–12.

Test very strongly compressed, carinate, perforate; spiral side approximately flat, reverse side low, convex; chambers depressed, numerous, convex, with limbate margins.

Similar to *Truncatulina lobatula*, but more depressed, and with more finely perforate walls.

Length, 1.22 mm.; breadth, 0.82 mm.

Locality.—Rancocas formation, Blue Ball, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

Genus TRUNCATULINA d'Orbigny.

TRUNCATULINA AKNERIANA (d'Orbigny).

Rotalina akneriana d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 156, Pl. VIII, figs. 13–15.

Truncatulina akneriana Reuss, 1866; Denks. Akad. Wiss. Wien, Vol. XXV, p. 160, No. 6.

Truncatulina akneriana Brady, 1884; Chal. Rept., Vol. IX, p. 663, Pl. XCIV, fig. 8, a, b, c.

"The superior face of the test of *Truncatulina akneriana* is flat, the inferior convex at the margin, but depressed toward the umbilicus;

Digitized by Google

and the convolutions are not completely involute on the inferior side, as in *Truncatulina lobatula*, but leave a portion of the earlier whorls visible at the center." (Brady, loc. cit.)

Diameter, 0.43 mm.

Locality.—Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This form is commonly associated with *Truncatulina lobatula* or *Truncatulina ungeriana*, or with both, and has a similar distribution.

TRUNCATULINA HAIDINGERII (d'Orbigny).

Rotalina haidingerii d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 154, Pl. VII, figs. 7, 9.

Truncatulina haidingerii Brady, 1884; Chal. Rept., Vol. IX, p. 663, Pl. XCV, fig. 7, a–c.

Test circular, biconvex, trochoid; volutions three, chambers marked by slightly depressed septa on inferior side, about twelve segments in the last convolution; aperture a small marginal slit.

Diameter, 0.58 mm.

Locality.—Rancocas formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

The above species is similar to *Truncatulina ungeriana*, but differs from it in being more vaulted and less depressed at the umbilicus. It is also a smaller form and is not so abundant, being rather rare in the middle marl bed. There is, furthermore, no distinct groove following the whorls upon the superior side, and the perforations are smaller than in *Truncatulina ungeriana*.

TRUNCATULINA LOBATULA (Walker and Jacob).

Nautilus lobatulus Walker and Jacob, 1798; Adams's Essays, Kanmacher's ed., p. 642, Pl. XIV, fig. 36.

Truncatulina lobatula Brady, 1884; Chal. Rept., Vol. IX, p. 660, Pl. XCII, fig. 10; Pl. XCIII, figs. 1, 4, 5; Pl. CXV, figs. 4, 5.

Test plano-convex, moderately vaulted; last volution consisting of seven or eight chambers, with very slightly depressed septa; septa more curved upon the superior (flat) surface; aperture a small, neatly shaped arch at the margin of the ultimate segment.

Diameter, 0.36–1.13 mm.

Locality.—Matawan formation, Marshalltown, New Jersey; Monmouth formation, Freehold, New Jersey; Rancocas formation, Vincentown, New Egypt, Mullica Hill, etc., New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Carboniferous to Recent.

The above species shows great variation. Professor Brady considers that the more convex varieties merge into *Truncatulina refulgens*, while flattened forms resemble *Truncatulina wuellerstorfi*. The regular-built convex varieties constitute the *Truncatulina boueana* of d'Orbigny, and the less regular the *Truncatulina variabilis* of the same author.

Digitized by Google

TRUNCATULINA REFULGENS (Montfort).

Cibicides refulgens, Montfort, 1808; Conch. Syst., Vol. I, p. 122, 31e genre.
Truncatulina refulgens, Brady, 1884; Chal. Rept., Vol. IX, p. 659, Pl. XCII, figs. 7–9.

Test subconical, superior surface complanate, inferior very much elevated; consisting of about eight chambers in the last convolution; sutures somewhat depressed upon the inferior (vaulted) surface; peripheral margin sharp; aperture an inframarginal opening near the base of the ultimate segment.

Diameter, 0.5 mm.

Locality.—Manasquan formation (?), Vincentown, New Jersey.

Geological distribution.—Cretaceous (Upper?) to Recent.

There is a possibility that this is an Eocene fossil, as it was obtained from some of the uppermost greensand of the New Jersey Cretaceous, which carries a number of Eocene fossils, together with some of late Cretaceous age. The specimens came from the upper marl bed at Vincentown, and only a very few forms were found.

TRUNCATULINA UNGERIANA (d'Orbigny).

Rotalina ungeriana, d'Orbigny, 1846; Foram. Foss. Bassin tert. Vienne, p. 157, Pl. VIII, figs. 16–18.
Truncatulina ungeriana, Brady, 1884; Chal. Rept., Vol. IX, p. 664, Pl. XCIV, fig. 9, a–d.

Test large, rotaliform, circular, coarsely porous, both sides moderately convex, unequal, depressed slightly on the inferior side at the umbilicus, consisting of three convolutions. The last volution consists of from ten to twelve limbate chambers. Septa arched; aperture a median semilunar slit.

Diameter, 0.78 mm.

Locality.—Rancocas formation, New Egypt, New Jersey; Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Cretaceous to Recent.

This species is rather common at New Egypt. In the upper marl bed the forms are much smaller, the shell being only about one-half the size of the New Egypt specimens.

TRUNCATULINA WUELLERSTORFI (Schwager).

Anomalina wüllerstorfi Schwager, 1866; Nov. Exped. geol. Theil., Vol. II, p. 258, Pl. VII, figs. 105, 107.

Test circular, coarsely porous; inferior surface convex, superior complanate; peripheral edge acute; chambers narrow; septa strongly curved, crescent-shaped with broad septal ridges, nine in the last convolution; aperture a small marginal cleft.

Diameter, 0.5 mm.

Locality.—Manasquan formation, Vincentown, New Jersey.

Geological distribution.—Upper Cretaceous to Recent.

This species is similar in its outline to figure 8, Plate XCIII, Challenger Report, Vol. IX. None of our specimens are as flat as figure 9 of the same plate, which Professor Brady considers the more typical

Digitized by Google

form. This author states that this species is described from the Pliocene deposits of Kar Nicobar by Schwager, but does not mention its earlier occurrence. It is an intermediate form between *Truncatulina lobatula* and *Anomalina ariminensis*.

Genus ANOMALINA, d'Orbigny.

ANOMALINA AMMONOIDES (Reuss).

Plate VI, fig. 5.

Rosalina ammonoides, Reuss, 1845–46; Verstein. böhm Kreide, pt. 1, p. 36, Pl. VIII, fig. 53; Pl. XIII, fig. 66.
Anomalina ammonoides, Brady, 1884; Chal. Rept., Vol. IX, p. 672, Pl. XCIV, figs, 2, 3.

Test nautiloid, coarsely porous, small, compressed; lateral surfaces nearly equally convex; depressed at the umbilici; peripheral edge round; aperture an arched, nearly medium slit upon the inner margin of the ultimate segment.

Diameter, 0.5–0.8 mm.

Locality.—Monmouth formation, Freehold, Bruere's pits on Crosswicks Creek, New Jersey; Rancocas formation, Vincentown, New Egypt, Timber Creek, etc., New Jersey.

Geological distribution.—Cretaceous to Recent.

ANOMALINA GROSSERUGOSA (Gümbel).

Plate VI, fig. 4.

Truncatulina grosserugosa, Gümbel, 1868; Abhandl. d. k. bayer. Akad. Wiss., Vol. X, p. 660, Pl. II, fig. 104, a. b.
Anomalina grosserugosa, Brady; Chal. Rept., Vol. IX, p. 673, Pl. XCIV, figs. 4, 5.
Anomalina grosserugosa, Sherborn and Chapman, 1889; Journ. Royal Microsc. Soc., p. 487, Pl. XI, fig. 34.

Test nautiloid, very coarsely porous, pores larger and more numerous upon inferior surface; both sides convex; umbilici distinct; peripheral margin round; chambers large, inflated, only eight in final convolution; septa nearly straight; aperture median, arched.

Diameter, 0.43–0.82 mm.

Locality.—Rancocas formation, Swedesboro, New Jersey; Manasquan formation, Vincentown, New Jersey.

The above species is very similar to *Anomalina ammonoides*, but differs from it in being relatively larger and thicker, with a smaller number of chambers in the final convolution, and also in its more obtusely rounded margin.

Genus PULVINULINA Parker and Jones.

PULVINULINA KARSTENI (Reuss).

Rotalia karsteni Reuss, 1855; Zeit. geol. Gesell., Vol. VII, p. 273, Pl. IX, fig. 6.
Rotalia karsteni Reuss, 1861; Sitz. Akad. Wiss. Wien., Vol. XLIV, pt. 1, p. 337.
Pulvinulina karsteni Brady, 1884; Chal. Rept., Vol. IX, p. 698, Pl. CV, figs. 8, 9.

Test circular, regularly built, convex on both sides, with obtuse-

Digitized by Google

angular periphery; composed of from three to four convolutions; septal markings on superior surface apparent as fine lines, while the lower surface shows slight depressions of the radiating septa; last convolution consisting of six or seven chambers; aperture a cleft on the lower side somewhat removed from the margin.

Length, 0.45–0.5 mm.

Locality.—Rancocas formation, Vincentown, Quinton, New Jersey.

Geological distribution.—Cretaceous to Recent.

PULVINULINA MICHELINIANA (d'Orbigny).

Rotalina truncatulinoides d'Orbigny, 1839; Foram. Canaries, Vol. II, pt. 2, p. 132, Pl. II, figs. 25–27.

Rotalina micheliniana d'Orbigny, 1840; Mém. Soc. géol. France, ser. 1, Vol. IV, p. 31, Pl. III, figs. 1–3.

Test orbicular, superior surface nearly flat, inferior highly convex, with an excavated umbilicus; spire complanate, with three convolutions; last volution consisting of ten or twelve chambers, angular, separated by straight septal lines below; aperture elongate, slightly removed from the margin.

Diameter, 0.45 mm.

Locality.—Rancocas formation, Blue Ball, Timber Creek, New Jersey.

Geological distribution.—Cretaceous to Recent.

This is not a common species, but was described by Prof. A. E. Reuss under the name *Rotalina nitida*, which he considered to be a young form of *Rotalina umbilicata* d'Orbigny. Dr. W. B. Carpenter considers that the *Rotalina umbilicata* of the Chalk is identical with *Rotalina soldanii* of the Vienna Tertiaries. Prof. H. B. Brady states that *Pulvinulina micheliniana* has its isomorph in *Truncatulina refulgens*, from which species it is distinguished by the more or less excavated umbilicus and the projecting apical margins of the segments. In the Challenger Report, however, *Rotalina nitida* is not given under the synonyms of *Pulvinulina micheliniana*, but Dr. Woodward has so considered it in his report on the Cretaceous Foraminifera of New Jersey, and it seems probable that this view is correct.

PULVINULINA RETICULATA Reuss, var. CARINATA Bagg.

Plate V, figs. 3a, 3b.

Test discoidal, both sides moderately convex, peripheral margin possessing a large double heel; surface of shell smooth and shining, marked upon the superior surface by broad, curving septal lines; convolutions about three; eight chambers in the last volution; inferior surface less distinct, umbilicus marked by radiating lines nearly straight, but not distinct beyond one-third their length; no aperture visible.

Diameter, 0.87 mm.

Locality.—Monmouth formation, Freehold, New Jersey.

Geological distribution.—Cretaceous.

Digitized by Google

GEOLOGICAL DISTRIBUTION OF THE FORAMINIFERA DESCRIBED IN THIS REPORT.

Species.	Formation.			
	Matawan.	Navesink.	Rancocas.	Manasquan.
LITUOLIDÆ.				
Haplophragmium concavum Bagg			×	
Haplophragmium irregulare Roemer			×	
Trochammina inflata (Montagu)			×	
TEXTULARIDÆ.				
Textularia agglutinans d'Orbigny			×	×
Textularia agglutinans var. porrecta Brady			×	
Textularia gibbosa d'Orbigny		×		
Textularia globulosa Ehrenberg		×		
Textularia gramen d'Orbigny			×	
Textularia sagittula Defrance			×	
Textularia turris d'Orbigny			×	
Verneuilina polystropha (Reuss)		×		
Verneuilina triquetra (von Münster)			×	×
Tritaxia tortilis (Reuss)			×	
Tritaxia tricarinata (Reuss)			×	×
Gaudryina pupoides d'Orbigny			×	
Clavulina communis d'Orbigny			×	
Clavulina parisiensis d'Orbigny			×	
Bulimina puschi Reuss		×		
Bulimina variabilis d'Orbigny		×		
Bolivina punctata d'Orbigny	×	×		
Bolivina textilaroides Reuss	×			
Pleurostomella subnodosa Reuss			×	
LAGENIDÆ.				
Lagena globosa (Montagu)			×	
Vitrewebbina lævis (Sollas)			×	
Vitrewebbina sollasi Chapman			×	
Nodosaria acuminata Reuss			×	
Nodosaria adolphinula (d'Orbigny)			×	
Nodosaria annulata Reuss		×	×	
Nodosaria communis (d'Orbigny)		×	×	
Nodosaria consobrina (d'Orbigny)	×			
Nodosaria consobrina var. emaciata Reuss	×		×	
Nodosaria farcimen (Soldani)			×	
Nodosaria filiformis d'Orbigny		×	×	
Nodosaria indifferens (Reuss)		×		
Nodosaria inornata (d'Orbigny)	×			
Nodosaria lævigata (d'Orbigny)			×	
Nodosaria longiscata d'Orbigny				×
Nodosaria multicostata d'Orbigny			×	
Nodosaria nitida d'Orbigny			×	
Nodosaria obliqua (Linné)	×	×	×	×
Nodosaria pauperata d'Orbigny				×
Nodosaria polygona Reuss	×	×	×	×
Nodosaria radicula (Linné)			×	
Nodosaria raphanus (Linné)			×	
Nodosaria rœmeri (Neugeboren)	×			
Nodosaria rotundata (Reuss)			×	
Nodosaria scabra (Reuss)				×
Nodosaria spinulosa (Montagu)				×

Digitized by Google

Geological distribution, etc.—Continued.

Species.	Formation.			
	Matawan.	Navesink.	Rancocas.	Manasquan.
LAGENIDÆ—continued.				
Nodosaria vertebralis (Batsch)			×	
Nodosaria williamsi Bagg			×	
Nodosaria zippei Reuss	×	×	×	×
Lingulina carinata d'Orbigny			×	
Frondicularia alata d'Orbigny			×	
Frondicularia angusta Nilsson, var. dimidia Bagg			×	
Frondicularia archiaciana d'Orbigny var. strigillata Bagg			×	
Frondicularia clarki Bagg		×		
Frondicularia gaultina Reuss	×			
Frondicularia inversa Reuss		×		
Frondicularia lanceola Reuss		×		
Frondicularia major Bornemann			×	
Frondicularia ovata Roemer	×		×	
Frondicularia pulchella Karrer	×			
Frondicularia reticulata Reuss		×		
Frondicularia verneuilina d'Orbigny	×			
Rhabdogonium roemeri Reuss	×			
Rhabdogonium tricarinatum d'Orbigny			×	
Rhabdogonium tricarinatum var. acutangulum Reuss	×			
Marginulina ensis Reuss		×	×	
Marginulina pediformis Bornemann	×			
Marginulina trilobata d'Orbigny	×	×		
Vaginulina legumen (Linné)	×		×	
Vaginulina strigillata Reuss		×		
Cristellaria acutauricularis (Fichtel & Moll)			×	
Cristellaria articulata (Reuss)			×	
Cristellaria cassis (Fichtel & Moll)			×	
Cristellaria crepidula (Fichtel & Moll)			×	
Cristellaria cretacea Bagg			×	
Cristellaria cultrata (Montfort)		×	×	
Cristellaria gibba d'Orbigny	×		×	
Cristellaria italica Defrance			×	
Cristellaria mamilligera Karrer			×	
Cristellaria megapolitana (Reuss)		×		
Cristellaria projecta Bagg			×	
Cristellaria rotulata (Lamarck)			×	×
Cristellaria secans Reuss		×		
Cristellaria trachyomphala Reuss			×	
Cristellaria triangularis d'Orbigny		×		
Cristellaria wetherellii (Jones)			×	
Flabellina cordata Reuss			×	
Flabellina sagittaria (Lea)			×	
Polymorphina compressa d'Orbigny			×	
Polymorphina communis (d'Orbigny)			×	
Polymorphina emersoni n. sp		×		
Polymorphina gibba (d'Orbigny)		×	×	
Polymorphina lactea (Walker & Jacob)		×	×	
Polymorphina lactea var. elongate Brady			×	
Polpmorphina oblonga d'Orbigny		×	×	
Polymorphina orbignii (Zborzewski)			×	
Polymorphina problema (d'Orbigny)			×	
Polymorphina regularis von Münster			×	

Digitized by Google

Geological distribution, etc.—Continued.

Species.	Formation.			
	Matawan.	Navesink.	Rancocas.	Manasquan.
GLOBIGERINIDÆ.				
Globigerina bulloides d'Orbigny			×	×
Globigerina bulloides var. triloba Reuss			×	×
Globigerina cretacea d'Orbigny		×	×	
ROTALIDÆ.				
Discorbina bertheloti (d'Orbigny)			×	
Truncatulina akneriana (d'Orbigny)				×
Truncatulina haidingerii (d'Orbigny)			×	
Truncatulina lobatula (Walker & Jacob)	×	×	×	×
Truncatulina refulgens (Montfort)				×
Truncatulina ungeriana (d'Orbigny)			×	×
Truncatulina wuellerstorfi (Schwager)				×
Anomalina ammonoides (Reuss)		×	×	
Anomalina grosserugosa (Gümbel)			×	×
Pulvinulina karsteni (Reuss)			×	
Pulvinulina micheliniana (d'Orbigny)			×	
Pulvinulina reticulata Reuss, var. carinata Bagg		×		
Total	20	32	79	19

Digitized by Google

Digitized by Google

PLATES.

Digitized by Google

Digitized by Google

PLATE I.

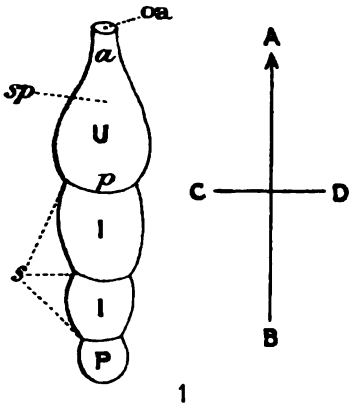
Digitized by Google

PLATE I.

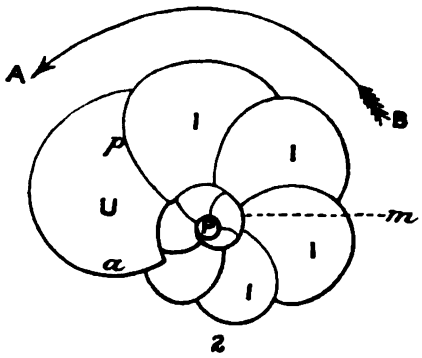
DIAGRAMS ILLUSTRATING DESCRIPTIVE TERMS.

	Page.
FIG. 1. Nodosarian type (Nodosaria, Vaginulina, Dentalina, Rhabdogonium, etc)	26
FIGS. 2, 3. Nautiloid type (Nonionina, Polystomella, Cristellaria, Anomolina, etc)	26
FIG. 4. Trochoid type (Discorbina, Pulvinulina, Rotalia, Truncatulina, etc)	26
FIG. 5. Textularian type (Textularia, Bolivina, Spiroplecta, Bulimina, etc)	26
FIG. 6. Milioline type (Miliolina, Biloculina, Triloculina, Spiroloculina, etc)	26

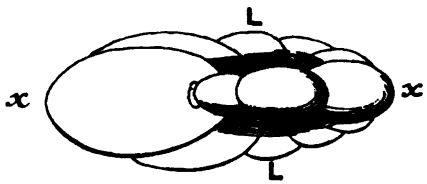
Digitized by Google



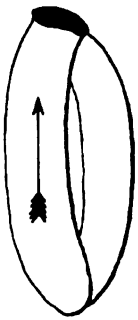
1



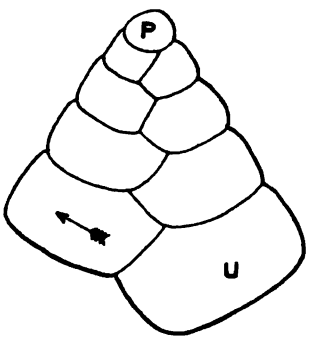
2



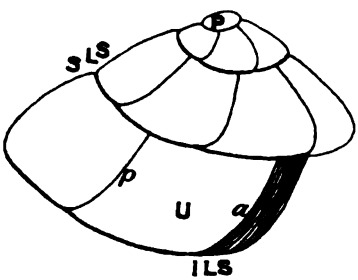
3



6



5



4

DIAGRAMS ILLUSTRATING DESCRIPTIVE TERMS

Digitized by Google

Digitized by Google

PLATE II.

Digitized by Google

PLATE II.

CRETACEOUS FORAMINIFERA.

	Page.
FIGS. 1a, 1b. HAPLOPHRAGMIUM CONCAVUM Bagg (x 48)	37
FIG. 2. VERNEUILINA TRIQUETRA (V. Münster) (x 14)	30
FIG. 3. BOLIVINA PUNCTATA d'Orb (x 142)	33
FIGS. 5a, 5b. VITREWEBBINA SOLLASI Chapman (x 3)	35
FIGS. 4a, 4b. VITREWEBBINA LÆVIS (Sollas) (x 3)	36
FIGS. 4a, 5b (bottom forms). FRONDICULARIA OVATA Roemer (x 5)	49
FIG. 4b (bottom form). FRONDICULARIA ALATA d'Orb (x 9)	46

Digitized by Google

1a

1b

2

4a

4b

3

5a

5b

H. C. H. del.

CRETACEOUS FORAMINIFERA

Digitized by Google

THE HELIOTYPE PRINTING CO. BOSTON

Digitized by Google

PLATE III.

Digitized by Google

PLATE III.

CRETACEOUS FORAMINIFERA.

	Page.
FIG. 1. NODOSARIA ZIPPEI Reuss (dimorphic form) (x 7)	45
FIG. 2a. NODOSARIA WILLIAMSI Bagg (lateral aspect) (x 38)	45
FIG. 2b. NODOSARIA WILLIAMSI Bagg (longitudinal section) (x 38)	45
FIG. 3. FRONDICULARIA MAJOR Bornemann (x 13)	49
FIG. 4. FRONDICULARIA CLARKI Bagg (x 10)	48
FIG. 5. FRONDICULARIA ARCHIACIANA d'Orb. var. STRIGILLATA Bagg (x 19)	47
FIG. 6. FRONDICULARIA RETICULATA Reuss (x 49)	50
FIG. 7a. FRONDICULARIA ANGUSTA Nilsson, var. DIMIDIA Bagg (lateral aspect) (x 21)	47
FIG. 7b. FRONDICULARIA ANGUSTA Nilsson, var. DIMIDIA Bagg (longitudinal section) (x 21)	47

Digitized by Google

1

2a

2b

5

4

3

6

7a

7b

H. H. Sc..

CRETACEOUS FORAMINIFERA

Digitized by Google

THE HELIOTYPE PRINTING CO., BOSTON

Digitized by Google

PLATE IV.

3069——6

Digitized by Google

PLATE IV.

CRETACEOUS FORAMINIFERA.

	Page.
FIG. 1a. FLABELLINA SAGITTARIA Lea (x 5)	59
FIG. 1b. FLABELLINA SAGITTARIA Lea (approaching FRONDICULARIA) (x 5)	59
FIG. 2a. FRONDICULARIA OVATA Roemer (x 7)	49
FIG. 2b. FRONDICULARIA OVATA Roemer (longitudinal section) (x 7)	49
FIG. 3. VAGINULINA STRIGILLATA Reuss (x 6)	53
FIG. 4. VAGINULINA LEGUMEN (Linne) (x 34)	53
FIG. 5a. CRISTELLARIA ITALICA Defrance (peripheral aspect) (x 45)	56
FIG. 5b. CRISTELLARIA ITALICA Defrance (lateral aspect) (x 45)	56

Digitized by Google

1a

1b

3

2b

2a

4

H. C. H. del.

5a

5b

CRETACEOUS FORAMINIFERA

Digitized by Google

THE HELIOTYPE PRINTING CO., BOSTON

Digitized by Google

PLATE V.

Digitized by Google

PLATE V.

CRETACEOUS FORAMINIFERA.

Page.

FIG. 1a. CRISTELLARIA PROJECTA Bagg (x 10) 57

FIG. 1b. CRISTELLARIA PROJECTA Bagg (longitudinal section) (x 10) 57

FIG. 2a. CRISTELLARIA CRETACEA Bagg (x 10) 55

FIG. 2b. CRISTELLARIA CRETACEA Bagg (longitudinal section) (x 10) 55

FIG. 3a. PULVINULINA RETICULATA Reuss, var. CARINATA Bagg (inferior aspect) (x 53) 68

FIG. 3b. PULVINULINA RETICULATA Reuss, var. CARINATA Bagg (superior aspect) (x 53) 68

Digitized by Google

1a

1b

2a

2b

3a

3b

H. C. H del.

CRETACEOUS FORAMINIFERA

Digitized by Google

THE HELIOTYPE PRINTING CO., BOSTON.

Digitized by Google

PLATE VI.

Digitized by Google

PLATE VI.

CRETACEOUS FORAMINIFERA.

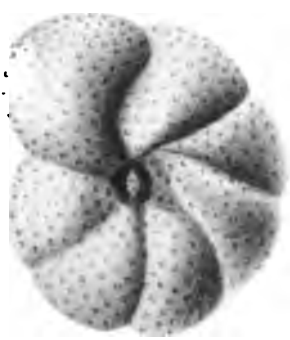
	Page.
FIG. 1. CRISTELLARIA CULTRATA (Montfort) (x 22)	55
FIG. 2. POLYMORPHINA COMMUNIS d'Orb (x 37)	60
FIG. 3. POLYMORPHINA EMERSONI Bagg (x 33)	60
FIG. 4. ANOMALINA GROSSERUGOSA (Gumbel) (x 86)	67
FIG. 5. ANOMALINA AMMONOIDES (Reuss) (x 70)	67

Digitized by Google

1

2

3



4

5

H. C. H. del.

CRETACEOUS FORAMINIFERA

Digitized by Google

Digitized by Google

INDEX.

	Page.
Analyses of specimens of Foraminifera	13
Analysis of glauconite	14
Anomalina ammonoides (Reuss)	67, 86
Anomalina grosserugosa (Gümbel)	67, 86
Anomalina wüllerstorfi Schwager = Truncatulina wuellerstorfi	66–67
Apiopterina d'orbignii Zborzewski = Polymorphina orbignii	62
Bailey, J. W., cited	15
Bibliography of the Foraminifera	17–25
Bolivina punctata d'Orbigny	31, 78
Bolivina textilaroides Reuss	34
Brady, H. B., bibliography of Foraminifera prepared by	17
Bulimina puschi Reuss	32–33
Bulimina variabilis d'Orbigny	33
Chapman, Frederick, acknowledgments to	9
Chemical analyses, *see* Analyses.	
Clark, W. B., acknowledgments to	9
cited	14, 16
letter of transmittal by	7
Cibicides refulgens Montfort = Truncatulina refulgens	66
Citharina strigillata Reuss = Vaginulina strigillata	53
Clavulina communis d'Orbigny	32
Clavulina parisiensis d'Orbigny	32
Credner, Hermann von, cited	16
Cristellaria acutauricularis (Fichtel and Moll)	54
Cristellaria articulata (Reuss)	54
Cristellaria cassis (Fichtel and Moll)	54
Cristellaria crepidula (Fichtel and Moll)	55
Cristellaria cretacea Bagg	55, 84
Cristellaria cultrata (Montfort)	55–56, 86
Cristellaria gibba d'Orbigny	56
Cristellaria italica (Defrance)	56, 82
Cristellaria mamilligera Karrer	56–57
Cristellaria megapolitana (Reuss)	57
Cristellaria projecta Bagg	57, 84
Cristellaria rotulata (Lamarck)	57–58
Cristellaria secans Reuss	58
Cristellaria trachyomphala Reuss	58
Cristellaria triangularis d'Orbigny	58–59
Cristellaria wetherellii (Jones)	59
Dall, W. H., acknowledgments to	9
Dawson, G. M., work on Cretaceous Foraminifera of Canada by	11
Dentalina acuminata Reuss = Nodosaria acuminata	36
Dentalina adolphinula d'Orbigny = Nodosaria adolphinula	37
Dentalina communis d'Orbigny = Nodosaria communis	37–38
Dentalina consobrina d'Orbigny = Nodosaria consobrina	38
Dentalina farcimen Reuss = Nodosaria farcimen (Soldani)	38–39
Dentalina filiformis Brady = Nodosaria filiformis d'Orbigny	39
Dentalina inornata d'Orbigny = Nodosaria inornata	39
Dentalina indifferens Reuss = Nodosaria indifferens	39
Dentalina multicostata, d'Orbigny = Nodosaria multicostata	40–41
Dentalina obliqua Jones, Parker, and Brady = Nodosaria obliqua	41
Dentalina pauperata d'Orbigny = Nodosaria pauperata	42
Dentalina pulchra Gabb = Nodosaria zippei Reuss	45
Dentalina roemeri Neugeboren = Nodosaria roemeri	43
Dentalina scabra Reuss = Nodosaria scabra	43–44
Dentalina steenstrupi Reuss = Nodosaria obliqua	41
Dentalina subnodosa Reuss = Pleurostomella subnodosa	34
Dentalina sulcata d'Orbigny = Nodosaria obliqua	41
Dentalina vertebralis Sherborn and Chapman = Nodosaria vertebralis	44
Discorbina bertheloti (d'Orbigny)	64
Flabellina cordata Reuss	59
Flabellina sagittaria (Lea)	59, 82
Flabellina reticulata Reuss = Frondicularia reticulata	50
Frondicularia alata d'Orbigny	46–47, 78
Frondicularia angusta Nilsson var. dimidia, Bagg	47, 80
Frondicularia archiaciana d'Orbigny var. strigillata (nov. var.)	47, 80
Frondicularia clarki Bagg	48, 80
Frondicularia gaultina Reuss	48
Frondicularia inversa Reuss	48
Frondicularia lanceola Reuss	49
Frondicularia major Bornemann	49, 80
Frondicularia ovata Roemer	49, 82
Frondicularia pulchella Karrer	49–50
Frondicularia reticulata Reuss	50, 80
Frondicularia verneuilina d'Orbigny	50
Gabb, W. M., cited	15
Gaudryina pupoides d'Orbigny	31–32
Geological distribution of the Foraminifera described, table showing	69–71
Goode, G. Brown, acknowledgments to	9

Digitized by Google

Page.

Glandulina lævigata d'Orbigny = Nodosaria lævigata 40
Glandulina rotundata Reuss = Nodosaria rotundata 43
Glauconite, analysis of 14
Globigerina bulloides d'Orbigny 63
Globigerina bulloides var. triloba Reuss. 63–64
Globigerina cretacea d'Orbigny 64
Globulina gibba d'Orbigny = Polymorphina gibba 61
Guttulina communis d'Orbigny = Polymorphina communis 60
Guttulina problema d'Orbigny = Polymorphina problema 62
Haplophragmium concavum Bagg 27, 78
Haplophragmium irregulare Roemer 27
Hillebrand, W. F., analyses of specimens of Foraminifera by 13
Hunt, T. Sterry, analysis of glauconite by 14
Johnson, C. W., acknowledgments to 9
Lagena globosa (Montagu) 34
Lea, Isaac, cited 15
Lenticulites rotulata Lamarck = Cristellaria rotulata 57
Lingulina carinata d'Orbigny 46
Linn, Alonzo, acknowledgments to 9
Literature of the Foraminifera (list of works) 17–25
Lyell, Charles, cited 15
Marginulina ensis Reuss 51–52
Marginulina pediformis Bornemann 52
Marginulina trilobata d'Orbigny 52
Marginulina wetherellii Jones = Cristellaria wetherellii 59
Morton, S. G., cited 15
Murray and Renard, cited 14
Nautiloid type of shell, figure showing 76
Nautilus acutauricularis Fichtel and Moll = Cristellaria acutauricularis 54
Nautilus cassis Fichtel and Moll = Cristellaria cassis 54
Nautilus crepidula Fichtel and Moll = Cristellaria crepidula 55
Nautilus inflatus Montagu = Trochammina inflata 27
Nautilus legumen Linné = Vaginulina legumen 53
Nautilus lobatus Walker and Jacob = Truncatulina lobatula 65
Nautilus obliquus Linné = Nodosaria obliqua 41
Nautilus radicula Linné = Nodosaria radicula 42
Nautilus raphanus Linné = Nodosaria raphanus 43
Nautilus spinulosus Montagu = Nodosaria spinulosa 44
Nautilus (Orthoceras) vertebralis Batsch = Nodosaria vertebralis 44
Nodosaria acuminata (Reuss) 36
Nodosaria adolphinula (d'Orbigny) 37
Nodosaria annulata Reuss 37
Nodosaria communis (d'Orbigny) 37–38

Page.

Nodosaria communis Woodward = Marginulina ensis Reuss 51–52
Nodosaria consobrina (d'Orbigny) 38
Nodosaria consobrina var. emaciata Reuss 38
Nodosaria farcimen (Soldani) 38
Nodosaria filiformis d'Orbigny 39
Nodosaria indifferens (Reuss) 39
Nodosaria inornata (d'Orbigny) 39–40
Nodosaria lævigata d'Orbigny 40
Nodosaria longiscata d'Orbigny 40
Nodosaria multicostata (d'Orbigny) 40–41
Nodosaria nitida d'Orbigny 41
Nodosaria nodosa Reuss = Pleurostomella subnodosa 34
Nodosaria obliqua (Linné) 41
Nodosaria pauperata d'Orbigny 42
Nodosaria polygona Reuss 42
Nodosaria radicula (Linné) 42
Nodosaria raphanistrum Woodward = Nodosaria zippei 45–46
Nodosaria raphanus (Linné) 43
Nodosaria roemeri (Neugeboren) 43
Nodosaria rotundata (Reuss) 43
Nodosaria scabra (Reuss) 43–44
Nodosaria spinulosa (Montagu) 44
Nodosaria vertebralis (Batsch) 44
Nodosaria Williamsi Bagg 45, 80
Nodosaria zippei Reuss 45–46, 80
Nodosarian type of shell, figure showing 76
Oolina simplex Reuss = Lagena globosa Montagu 34
Orthoceras farcimen Soldani = Nodosaria farcimen 38
Palmula sagittaria Lea = Flabellina sagittaria 59–60
Planularia angusta Nilsson = Frondicularia angusta (Nilsson) var. dimida Bagg 47
Planularia cuneata Morton = Flabellina sagittaria 59–60
Pleurostomella subnodosa Reuss 34
Polymorphina compressa d'Orbigny 60
Polymorphina communis (d'Orbigny) 60, 86
Polymorphina emersoni n. sp. 60–61, 86
Polymorphina gibba (d'Orbigny) 61
Polymorphina lactea (Walker and Jacob) 61
Polymorphina lactea elongate variety Brady 61
Polymorphina oblonga d'Orbigny 62
Polymorphina orbignii (Zborzewski) 62
Polymorphina problema (d'Orbigny) 62
Polymorphina regularis von Münster 63
Pulvinulina karsteni (Reuss) 67–68
Pulvinulina micheliniana (d'Orbigny) 68
Pulvinulina reticulata var. carinata Bagg 68, 84
Quenstedt, F. A., cited 35
Reuss, A. E., cited 16
Rhabdogonium roemeri Reuss 51
Rhabdogonium tricarinatum d'Orbigny 51
Rhabdogonium tricarinatum var. acutangulum Reuss 51
Robulina articulata Reuss = Cristellaria articulata 54

Digitized by Google

	Page.
Robulina cultrata d'Orbigny = Cristellaria cultrata (Montfort)	55-56
Robulina megapolitana Reuss = Cristellaria megapolitana	57
Robulina trachyomphala Reuss = Cristellaria trachyomphala	58
Robulus cultratus Montfort = Cristellaria cultrata	55-56
Rosalina ammonoides Reuss = Anomalina ammonoides	67
Rosalina bertheloti d'Orbigny = Discorbina bertheloti	64
Rotalia karsteni Reuss = Pulvinulina karsteni	67-68
Rotalina akneriana d'Orbigny = Truncatina akneriana	64-65
Rotalina haidingerii d'Orbigny = Truncatina haidingerii	65
Rotalina mitcheliniana d'Orbigny = Pulvinulina mitcheliniana	68
Rotalina truncatulinoides d'Orbigny = Pulvinulina mitcheliniana	68
Rotalina ungeriana d'Orbigny = Truncatulina ungeriana	66
Saracenaria italica Defrance = Cristellaria italica	56
Say, Thomas, cited	15
Serpula lactea Walker and Jacob = Polymorphina lactea	61
Sherborn, C. D., acknowledgments to	9
bibliography of Foraminifera prepared by	17
index to genera and species of the Foraminifera prepared by	17
Spirolina irregularis Roemer = Haplophragmium irregulare	27
Stanton, T. W., acknowledgments to	9
Strata, classified table of	16
Terms used in description of forms, explanation of	25-26
Textularia agglutinans d'Orbigny	28
Textularia agglutinans var. porrecta Brady	28
Textularia gibbosa d'Orbigny	29
Textularia globulosa Ehrenberg	29
Textularia gramen d'Orbigny	29
Textularia sagittula Defrance	29-30
Textularia turris d'Orbigny	30
Textularian type of shell, figure showing	76
Tritaxia tortilis (Reuss)	31
Tritaxia tricarinata (Reuss)	31
Trochammina inflata (Montagu)	27
Trochoid type of shell, figure showing	76
Truncatulina akneriana (d'Orbigny)	64-65
Truncatulina grosserugosa Gümbel = Anomalina grosserugosa	67
Truncatulina haidingerii (d'Orbigny)	65
Truncatulina lobatula (Walker and Jacob)	65
Truncatulina refulgens (Montfort)	66
Truncatulina ungeriana (d'Orbigny)	66
Truncatulina wuellerstorfi (Schwager)	66-67
Tyrrell, J. B., work on Cretaceous Foraminifera of Manitoba by	11
Vaginulina legumen (Linné)	53, 82
Vaginulina strigillata Reuss	53, 82
Vaginulina tricarinata d'Orbigny = Rhabdogonium tricarinatum	51
Vermiculum globosum Montagu = Lagena globosa	34
Verneuilina polystropha (Reuss)	30
Verneuilina triquetra (Münster)	30-31, 78
Vitrewebbina lævis (Sollas)	36, 78
Vitrewebbina sollasi Chapman	35-36, 78
Webbina lævis = Vitrewebbina lævis	36
Williamson, W. C., cited	25
Woodward, Anthony, bibliography of Foraminifera prepared by	17
cited	44
synopsis of Cretaceous Foraminifera prepared by	12
Woodward and Thomas, work on Cretaceous Foraminifera of Minnesota by	11
Woolman, Lewis, acknowledgments to	9

Digitized by Google

Digitized by Google

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 89

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

SOME LAVA FLOWS

OF THE

WESTERN SLOPE OF THE SIERRA NEVADA, CALIFORNIA

BY

F. LESLIE RANSOME

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Letter of transmittal	7
Introduction	9
General outline of the physiography of the region	10
The occurrence and distribution of the lavas (latites)	14
Petrography of the latites and of the other volcanic rocks associated with them.	27
The Table Mountain flow	28
The biotite-augite-latite	37
The Dardanelle flow	46
Associated volcanic rocks	52
Chemical composition of the Sierra Nevada latites	57
Classification of the latites	59
The evidence of the lava flows as regards orogenic movements	69
Summary	71
Index	73

ILLUSTRATIONS.

PLATE	I. Diagram showing the position of the area embraced by the map.	9
	II. Map of a portion of the region drained by the Stanislaus River, showing the distribution of the latites and other Neocene lavas and tuffs	12
	III. The Dardanelles from the west, showing the hummocky granitic surface in the foreground and the crest of the Sierra Nevada in the distance	14
	IV. Table Mountain flow resting unconformably upon beds of fragmental andesite, south of Squaw Hollow	20
	V. Contact between the massive latite of the Table Mountain flow and the underlying andesitic breccia, 1¼ miles east of Clover Meadow	22
	VI. Andesitic conglomerate underlying Table Mountain flow, 1¼ miles east of Clover Meadow	24
	VII. View of bluff which terminates the ridge about 2 miles east of Clover Meadow, showing the stratification of the andesitic beds	26
	VIII. Spheroidal facies of augite-latite of the Table Mountain flow	28
	IX. Columnar facies of augite-latite of the Table Mountain flow	30
	X. View of the Dardanelles from a high point to the south, looking over the canyon of the Middle Stanislaus River	32
	XI. Microsections of latites (semidiagrammatic)	34

Digitized by Google

Digitized by Google

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., June 19, 1897.

SIR: I have the honor to transmit herewith an illustrated paper by Dr. F. L. Ransome on some lavas from California that are regarded as intermediate between trachytes and andesites. It may be noted that these rocks occupy the same position among the effusives that certain of the rocks called monzonite by Brögger do among the granolites.

It is recommended that the paper be published as a bulletin.

Very respectfully, yours,

H. W. TURNER,
Geologist.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

Digitized by Google

Digitized by Google

Digitized by Google

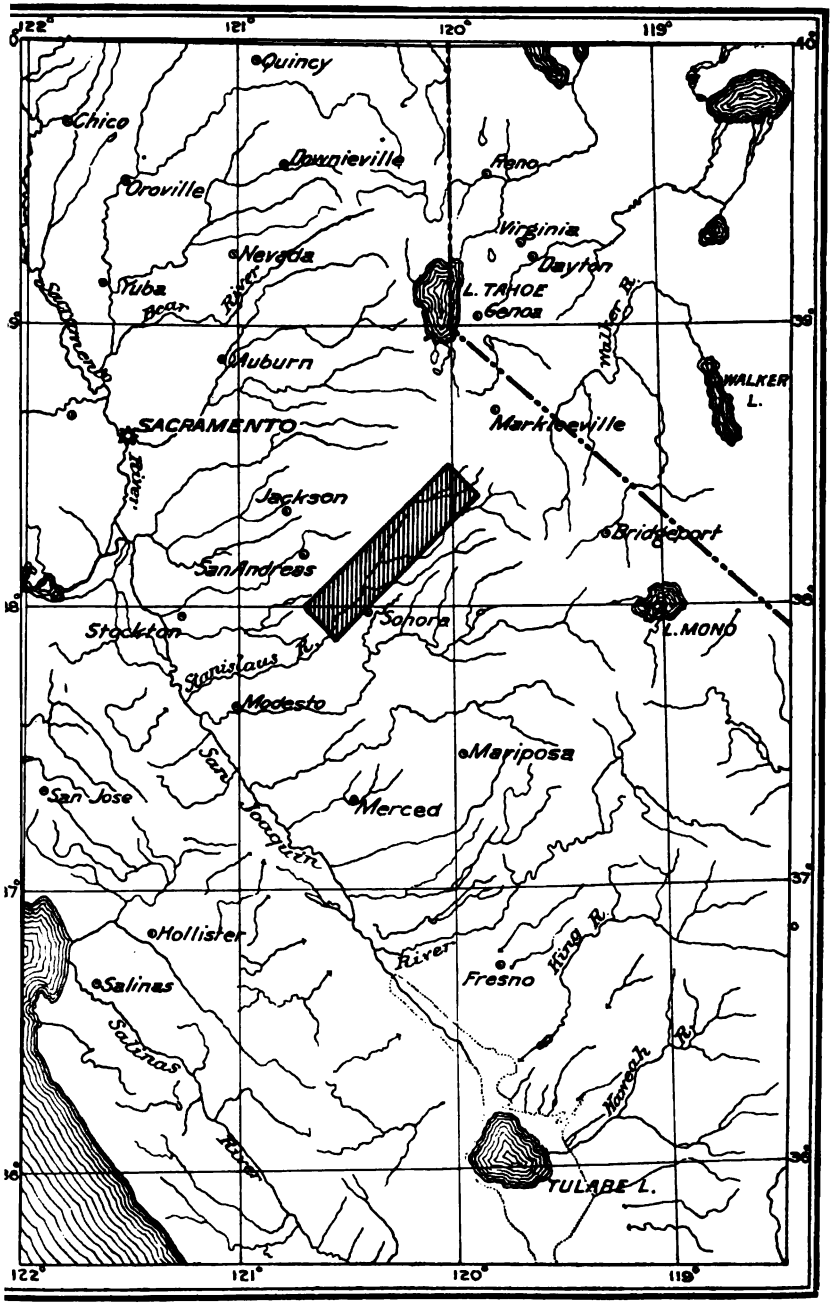


DIAGRAM SHOWING THE POSITION OF THE AREA EMBRACED BY THE MAP (PL. II).

Digitized by Google

SOME LAVA FLOWS OF THE WESTERN SLOPE OF THE SIERRA NEVADA, CALIFORNIA.

By F. Leslie Ransome.

INTRODUCTION.

The field relationships of the rocks described in the following paper were studied during the summers of 1895 and 1896, while I was engaged in geologically mapping portions of the Sonora and Big Trees quadrangles, under the direction of Mr. H. W. Turner. It was seen that this particular set of lavas offered a promising field for more detailed work than could be given to the region as a whole, and Mr. Turner kindly suggested that I should undertake their investigation as a special problem, to be carried along in conjunction with the regular areal work of the quadrangles. It was found that, in addition to the andesitic tuffs and breccias (designated upon the completed folios of the Gold Belt of California "Neocene andesite-tuff," or "Neocene andesite"), which are so widely and monotonously developed over the broad western slope of the Sierra Nevada, there occurs within the district studied another series of lavas in the form of massive flows, of much more limited distribution. They are in some cases closely associated with the breccias and tuffs, but are always readily recognized by their prevailingly massive character and by certain very distinctive lithological features. Taken as a whole, they form a series of superimposed flows, extending in a southwest direction from some as yet unknown source near the crest of the range in Alpine County down to the little village of Knights Ferry, in Stanislaus County, on the border of the Great Valley—a distance of more than 60 miles as the crow flies. Only one of the flows is known to have extended the whole distance, and they have all suffered considerable dissection through the very incisive gashing of the present streams, but in a general way the line of flow may be said to follow the course of the Stanislaus River. These flows were poured out within the period of eruptive activity, during which the andesitic breccias and tuffs were spread for hundreds of square miles over the western slope of the Sierra; but their eruption was immediately preceded by an interval of sharp erosion, which cut out the channels down which they flowed

Digitized by Google

toward the valley. Subsequently they were again partly covered by fresh andesitic breccia, especially in the higher portions of the range.

The distinctive chemical feature of these rocks is a rather high percentage of total alkalies, with the potash somewhat in excess of the soda. Chemically they stand between typical andesites and typical trachytes, and belong to a general chemical group of the effusive rocks which it seems necessary to classify under a new name. Without anticipation of a discussion which has its proper place after the rocks themselves have been described, the name *latite* (derived from the Italian province of Latium or Latia, where rocks closely related to those described in the present paper occur abundantly), may be considered for the present as used merely to indicate the group of lavas which form the subject of the present paper, for the purpose of avoiding confusion with the ordinary clastic andesites abundant in the same field.

The laboratory work embodied in the preparation of this paper was carried on in the petrographical laboratory of Harvard University, and my thanks are due to Professor Wolff for the excellent facilities there enjoyed. I am also indebted to Mr. Turner not only for the original permission to undertake the work, but for generously aiding it in many ways and for furnishing field notes of such occurrences of the latites as fell within his own portions of the general area.

GENERAL OUTLINE OF THE PHYSIOGRAPHY OF THE REGION.

The accompanying map (Pl. II) embraces a rectangular strip of country 63 miles in length and 14.5 miles in width, with its longer dimension lying very nearly northeast and southwest. It includes portions of the Oakdale, Sonora, Jackson, Big Trees, Dardanelles, and Pyramid Peak atlas sheets, and the general position of the district covered is indicated in the annexed diagram (Pl. I). Considerably more than half the area lies within the Big Trees sheet. The extreme southwestern portion, lying west of longitude 120° 30′ and south of latitude 38°, is from the northeast corner of the unfinished Oakdale sheet. The topography is here only partly indicated, and the areas of latite are drawn with approximate outlines subject to revision when the region is examined in detail with a finished topographical map. A similar explanation should also be made with regard to the corner of the map lying east of longitude 120°, which is a part of the Dardanelles sheet. The work in this area was limited to a rapid reconnaissance, before the completion of the topographical base, and the areas of Neocene lavas will require slight modifications and considerable additions when the areal geology of the Dardanelles quadrangle is worked out in full.

The elevations on the map range from a general altitude of about 500 feet, near Knights Ferry, to 9,529 feet, on the summit of Dardanelle Cone, in Alpine County, corresponding to an average grade of 150 feet per mile for this portion of the Sierra slope. As a whole, this area is

Digitized by Google

practically destitute of alluvial valley bottoms, and is drained by streams of torrential character. It is traversed from end to end by the comparatively young consequent Stanislaus River, with its two principal branches, the North and the Middle forks, and may be regarded as a thoroughly typical transverse strip of the great tilted and dissected peneplain which forms the western slope of the Sierra Nevada. The rocks upon which this somewhat uneven peneplain has been carved are those of the so-called "Bed-rock series" of the Gold Belt folios, and are of Juratrias and earlier age. In the foothill region they consist of closely compressed clay slates, schists, limestones, quartzites, and various igneous rocks, while in the higher portions of the slope gneissoidal and granitic rocks prevail.

Toward the end of the base-leveling process, which, as shown by Diller[1] and Lindgren[2] for other portions of the Sierra, lasted at least into the Miocene, the series of volcanic eruptions began which continued through the Pliocene, and which ended by covering the old surface far and wide with a blanket of clastic andesitic material in the form of breccias, rolled gravels, and fine tuffs. At the same time began the differential elevation which has given the peneplain its present slope of about two degrees to the southwest. According to Lindgren,[3] there is still recognizable a peneplain of Cretaceous age in the common altitude of many of the higher peaks of the middle Sierra, but no survival of such an intermediate stage of base-leveling has been detected in this region of the Stanislaus drainage.

The old surface revealed to-day by the stripping off of a great part of its andesitic cover is by no means a perfectly even one. If the sharp V-shaped canyons of post-Tertiary date were all filled up, and the remnants of the Tertiary volcanic cover quite removed, there would still remain a surface of gentle relief surmounted by occasional monadnocks. On the whole, though, it would be a topography of greatly subdued relief when contrasted with the possibilities for alpine types of form suggested by the nearly vertical schistose rocks and batholithic plutonic masses out of which it was carved.

The peneplain character has not been equally well preserved in all portions of the region. In the foothill districts it is recognizable only in a very general way, erosion having largely obliterated the old surface or obscured it by the etching out of later and local lowlands. The reason for this is threefold: The foothill regions are not only composed of belts of highly tilted heterogeneous rocks, originally unfavorable to the production of an ideal peneplain, but in addition to this they were probably never so thoroughly covered by the coarse andesitic breccias as were the higher portions of the slope. Moreover, the lack of homogeneity in the underlying rocks has led to the rapid development in Pleistocene time of small subsequent streams along belts of weaker

[1] Topographical revolution on the Pacific coast: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, pp. 419–421.

[2] Age of the auriferous gravels of the Sierra Nevada: Jour. Geol., Vol. IV, 1896, pp. 893 and 898.

[3] Loc. cit., p. 897.

Digitized by Google

rocks, and thereby effected a far more widespread degradation of the surface than in the higher region presently to be described, where the underlying rocks are not only more homogeneous, but have been more thoroughly protected from attack.

Nowhere within the area of the map is the old peneplain character better preserved than in the region included between the North Fork and the Middle Fork of the Stanislaus River. All the higher ridges are capped by andesitic breccia, and as a rule present flat, even tops, with a very gently ascending grade to the northeast. As these ridge tops are generally bare, or covered only with patches of low-growing shrubs and scattered trees, they are the natural routes of travel through the district and are followed by the sheep and cattle herders, who make use of the higher mountain meadows during the summer months. In contrast with the bare or open character of the ridges, the intervening slopes and canyons are generally heavily forested with noble trees, including the famous "mammoth trees" (*Sequoia gigantea*), the more graceful and scarcely less majestic "sugar pine" (*Pinus lambertiana*), and the massive "yellow pine" (*Pinus ponderosa*).

Following one of the ridges the traveler may ride for hours on a scarcely perceptible grade toward the northeast, with a wide prospect over the treetops on either hand and a view of similar ridges in the distance. But if, as Whitney says, speaking of the mining regions of the Sierra, "he turn and attempt to make his way across the country, in a line parallel with the crest of the range, he will discover that this apparent plain is cut into by the gorges or canyons in which the present rivers run in a most extraordinary manner; he will find it several hours' work to descend into one of these and rise again to the general level on the other side, even if he be assisted by a well-beaten trail."[1]

The drainage of the middle portion of the slope differs from that of the foothill region in the absence or insignificance of purely subsequent streams. The larger tributaries show a tendency to flow straight down the tilted peneplain, entering the main trunk streams obliquely, and frequently after running for a long distance nearly parallel with them, as in the case of Beaver Creek and the North Fork of the Stanislaus, the former being at one point apparently in imminent danger of capture by the latter. As a result of this consequent system of drainage, the deep canyon of the Middle Fork receives practically no tributaries from its southern side, the brink of its canyon wall being the divide. The North Fork shows a similar poverty in tributaries on its northwest side, streams frequently heading close up to the brink of its gorge, but generally diverging from it at a small angle toward the west and running finally into the Mokelumne River to the northwest. In other words, the general direction of consequent flow roughly bisects the angle made by the two main forks of the Stanislaus. The whole area is characterized by very active but concentrated erosion. The larger

[1] Auriferous Gravels of the Sierra Nevada, Cambridge, 1880, pp. 63–64.

Digitized by Google

Digitized by Google

Digitized by Google

streams, having cut through the Neocene cover of andesitic breccia, are still energetically sinking their steep-walled, V-shaped canyons into the underlying granitic rocks. These canyons as yet show little tendency to widen out into valleys, and remnants of the former extensive covering of andesite are often preserved on their very brinks. The vigorous nature of this trenching is well shown in the deep canyon of the Mokelumne River, of which a small portion comes within the map just north of Bear Valley, and also in the whole canyon of the Middle Stanislaus. There are probably few better illustrations of a young V-shaped canyon than can be seen by looking westward from a point about halfway down the trail which is shown descending into the gorge a mile and a half west of Mount Knight.

From Clover Meadow eastward the character of the country changes, although the change is not an abrupt one. The various residual andesitic ridges which have converged just west of Clover Meadow extend eastward as a single main ridge into the area of the Dardanelles quadrangle, between Highland Creek on the north and the Middle Stanislaus River on the south. About 2 miles east of Clover Meadow the ridge ends in a steep bluff about 400 feet in height. The brink of this declivity affords a view (Pl. III) which, aside from its somewhat stern beauty, is of considerable interest. For many miles to the northeast the eye overlooks a wild, hummocky surface of bare and glaciated granite,[1] stretching up toward the crest of the range, its dazzling whiteness being only partly relieved by a sparse growth of pines. In the near foreground the bald hummocks are interspersed with small, bright-green meadows, fringed with quivering aspens, and usually inclosing a lakelet. Immediately to the east, and just across the low, hummocky foreground, the dark and rugged peaks of the Dardanelles rise to an altitude 9,529 feet above the sea. The nearest peak, which may be conveniently called the West Dardanelle, can be plainly seen to be made up of a series of nearly horizontal volcanic layers, resting upon the granite and capped by a heavy flow of dark columnar lava, forming vertical cliffs several hundred feet in height. Beyond the Dardanelles appear the higher peaks forming the crest of the Sierra, also in part capped by volcanic rocks in nearly horizontal attitudes. These embrace some well-stratified andesitic tuffs, as observed by Turner[2] on the summit of Arnot Peak at an elevation of 10,000 feet.

This higher portion of the Sierra slope can not, then, like that west of Clover Meadow, be characterized as a series of more or less linear lava-capped ridges, separated by narrow canyons. The possibility of riding easily along the flat ridge tops has ended with the bluff upon which the observer stands. From here on to the summit the Neocene volcanic covering has been so thoroughly dissected and carried away that only a few scattered remnants testify to its once great extent.

[1] The term granite is used throughout this paper in a general sense, including all the "granodiorite," quartz-mica-diorite, etc., as well as true granite.

[2] Geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 708.

Digitized by Google

The region is best described as a rolling and hummocky granitic slope—a portion of the old peneplain modified by ice action and by recent erosion. Above this old surface stand isolated peaks and clusters of peaks, often true flat-topped buttes, composed of volcanic materials. Distinctly below it are the deep trenches of the larger streams, their character being well shown in the fine gorge of the Middle Stanislaus, 4 miles southeast of Clover Meadow. An idea of the general character of the region may be gained from Pl. X (p. 32), which is a view of the Dardanelles from the south, looking across the canyon of the Stanislaus.

The foregoing account of the physiography of the region embraced in the accompanying map (Pl. II) is little more than a bare outline, intended to present some picture of the old uneven peneplain, with its Neocene cover of fragmental andesite, down which the latitic lavas flowed, and of the general character of the erosion by which it has since been modified. No reference has been made to the influence of ice action upon the drainage, for the reason that there is no patent evidence that the important streams have retained any traces of ice interference. Definite moraines are rare, and although a few morainal patches occur on some of the ridges as low down as 5,500 feet, they are not shown on the present map. Various details of topography which are closely connected with the occurrence and distribution of the latites can be more intelligibly discussed under that head than in a general preliminary sketch, and will be for the present deferred.

THE OCCURRENCE AND DISTRIBUTION OF THE LAVAS (LATITES).

The latites were early differentiated in the field into three varieties, belonging to at least three distinct flows. These are, in the order of their geological sequence: (1) a dark, compact augite-latite of somewhat basaltic aspect, with conspicuous tabular crystals of labradorite and smaller phenocrysts of augite, which for convenience will be referred to as the Table Mountain facies; (2) a moderately dark-gray biotite-augite-latite, in which glistening tablets of biotite are the most conspicuous phenocrysts; (3) a dark, very compact augite-latite, with small, scattered phenocrysts of labradorite and augite, which may be called the Dardanelle facies from its occurrence on the extreme summit of the West Dardanelle.

The Table Mountain facies forms the longest flow of the series, having been traced from the West Dardanelle, where its surface attains an elevation of about 8,600 feet, down to Knights Ferry, where it forms plateaus, with black, bowlder-strewn surfaces, about 500 feet above sea. The rough, bowlder-like masses, from a foot to 2 feet in diameter, locally known as "nigger-heads," which are frequently abundant on the surface of the flow near Knights Ferry, are of the same character as the solid lava beneath them; and as the latites rarely show any

Digitized by Google

Digitized by Google

Digitized by Google

signs of weathering into soil, these were possibly originally loose fragments borne along on the surface of the lava stream.

My information concerning this portion of the Table Mountain flow is incomplete. It is known to extend almost continuously for 7 miles up both banks of the river, to Byrnes Ferry, forming irregular, plateau-like areas which break off abruptly on the river side in vertical columnar cliffs. These areas were evidently continuous at one time, but have been dissected by the river, now flowing several hundred feet below them. Andesitic breccia is reported by Turner[1] beneath the Table Mountain flow at Byrnes Ferry, and a considerable bed of similar breccia occupies the same relative position just south of McCartney Creek, about 4 miles northeast of Knights Ferry.

Near Byrnes Ferry the flow turns eastward, leaving the river and entering the edge of the Sonora quadrangle just west of Montezuma, or about latitude 37° 53′. Here it again resumes a northeasterly course, running generally parallel with the Stanislaus River at an average distance of about 5 miles to the southeast, until it enters the southern border of the Big Trees quadrangle, just west of Shaws Flat. It is this section of the flow that is known as the Tuolumne Table Mountain, a physiographical feature of considerable natural and historical interest. The old river gravels in the Neocene channel, beneath the so-called basalt, being auriferous, were actively exploited during the earlier days of mining activity. The line of famous Mother-Lode veins, passing through Angels, Carson Hill, Rawhide, and Quartz Mountain, runs beneath the lava near Rawhide, and reappears on the southern side as a heavy vein, determining a small southeast spur shown on the map. Being thus in the center of one of the most productive mining districts in the State, several references to the Tuolumne Table Mountain are found in the older geological literature of California. Trask,[2] writing in 1856, says:

> This celebrated locality, of which so much has been said and written of late, is one of the most remarkable and interesting places to be found in this State.
>
> That portion of the mountain which has so recently attracted attention on account of the placer deposits found beneath its surface is situated near the towns of Sonora and Columbia, being about equidistant from either locality. A portion of Shaw's Flat is situated immediately at its base. The superior portion of the mountain is composed of basaltic rock having the prismatic form; but in a few instances, at different points, it assumes the pentagonal shape so common to the columnar form of this rock.
>
> I have traced this basaltic overflow in an east and west direction for the distance of nearly 40 miles on its course, and it is probable that it will be found to extend to a much greater distance eastward than at present known.
>
> . . . . . .
>
> Its breadth is very variable throughout its course, in no instance, I believe, less than 400 feet, and often one-fourth of a mile. It seems to have followed the course

[1] The rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part , 1894, p. 491.

[2] Report on the Geology of Northern and Southern California, Sacramento, 1856; State Senate Doc. 4, p. 20.

Digitized by Google

of a stream, filling its bed and banks, and to have flowed in this course for the entire length that it is now observable upon the surface.

To the east [*sic*] of Columbia it crosses the present bed of the Stanislaus at two different places, but what its position beyond this may be is at present unknown with any degree of certainty. From the relative position of the Stanislaus at the present time, the evidences are almost demonstrative that at the period of its occurrence it flowed into and down the former bed of this river, displacing the latter and filling up the space between its banks. The depth of the banks to the bed may be pretty accurately measured by the thickness of the basalt above that bed, which is about 100 feet on a general average.

Professor Whitney, in his volume on the geology of California, devotes several pages to a description of this portion of the flow, and of the auriferous gravels beneath the lava, accompanying his report with illustrations and sections. His account is too long to quote entire, but the following portions are pertinent to the lava flow itself, and are characterized by Whitney's usual graphic descriptive power:

One of the most striking features in the topography and geology of Tuolumne County is the so-called "Table Mountain," a name given throughout the State to the flat table-like masses of basaltic lava which have been rendered so conspicuous by the erosion of the softer strata on each side, and which now exist as elevated ridges, dominating over the surrounding country and remarkable for their picturesque beauty, but still more so on account of the important deposits of auriferous detritus which lie beneath them.

The Table Mountain of Tuolumne County is a flow of lava originating in the lofty volcanic region beyond the Big Trees of Calaveras. . . . . It comes down on the north side of the Stanislaus, forming a nearly continuous ridge, elevated more than 2,000 feet above the river. Just below Abbeys Ferry ("Abbott Ferry" on map) the Stanislaus has broken through the once continuous basaltic ridge, which has been irregularly worn away for some distance from the river, but which reappears as a continuous mountain a little southwest of Columbia and continues on the south side of the river, forming a conspicuous feature of the scenery as far as Knights Ferry, a distance of about 20 miles from the point where it crosses the river and enters Tuolumne County. As seen from a distance, this Table Mountain reveals its origin at once in the contrast between the long straight line of its upper edge and the broken and curving ones which eroded hills of the auriferous slates everywhere exhibit. Its dark color and the comparative absence of trees or shrubs on its top and sides also indicate very clearly that the material of which it is composed is very different from that of the surrounding hills.

. . . . . .

On approaching Table Mountain and examining the material of which it is composed, and the position which it occupies, it is seen at once that it is a vast lava flow, of which the upper surface remains very nearly at the level and with the form which it originally had at the time of its consolidation, while the edges and the surrounding country have been denuded and washed away, so that the topography of the region is entirely different from what it was; in fact it is almost the reverse of it. No one can deny that a stream of melted lava, running for 40 miles down the slope of the Sierra, must have sought and found a depression or valley in which to flow, for it is impossible that it should have maintained, for any distance, a position on the crest of a ridge. Nor could the valley of the Stanislaus, now 2,000 feet deep, have existed at that time, for this flow of lava is clearly seen to have crossed it at Abbeys Ferry. The whole face of the country must, therefore, have undergone an entire change since the eruption took place during which this mass of lava was poured out. . . . .

The summit of Table Mountain is occupied by a heavy bed of basaltic lava, of a very dark color and dense texture. It is occasionally distinctly columnar, and

Digitized by Google

appears to have all been poured out in one flow, as there are no partings or divisions perceptible in the mass, which in the vicinity of Sonora is from 140 to 150 feet in thickness. Its width, at a point near the Buckeye Tunnel, was found to be about 1,700 feet. The surface of the basalt is very nearly level, with a gentle slope down the valley.[1]

In his volume on the auriferous gravels,[2] the same writer summarizes his earlier account of the mountain, adds some further notes, and appends an outline map showing the approximate extent of the dissected lava flow between Abbeys Ferry and Knights Ferry. He also gives several transverse sections showing the structure of the mountain as revealed by mining operations. He speaks of the "basalt" overlying the andesite breccia, a relation which both Mr. Turner and I have confirmed at several points.

To the descriptions quoted there is little to be added concerning this portion of the flow, save to note that it attains a width of three-fourths of a mile northwest of Montezuma, and that the columnar structure is a decidedly noticeable feature of the dark crags which surround the mountain in this region, rendering it an almost impassable barrier, and its level top a secure resort for hawks and eagles. Roads skirt the cliffs on either side, but a practicable route across the line of the flow is found only where the volcanic cap has been cut through by erosion, effected by an undermining of the softer underlying rocks. The main stage road, connecting Sonora with the Great Valley, passes through such a gap about three-fourths of a mile northwest of Shaws Flat.

The extent of the general erosion that has transformed the old Neocene lava stream into the most imposing and continuous mountain mass in the vicinity is well shown in one of Whitney's wood cuts,[3] which pictures the Table Mountain from the southeast, probably near Chinese Camp, with the Bear Mountains (monadnocks) rising in the distance above its even crest line.

North of Shaws Flat, the Table Mountain flow turns westward toward the Stanislaus River. Just west of Springfield it appears to rest in a shallow trough eroded in andesitic breccia, but this relation could not be definitely established. It terminates a mile to the south of Parrott Ferry in a columnar cliff overlooking the canyon of the Stanislaus, the stream flowing a thousand feet below the bottom of the lava. Looking northward, across the river, the continuation of the flow can be seen as a dark capping upon the summit of a granite peak rising precipitously from the water's edge, just west of the ferry. The base of the latite is here 1,100 feet above the bottom of the canyon and rests directly upon the granite. The distance between the two dissevered portions of the flow is just under 1¼ miles.

From Parrott Ferry northward the flow has been dissected into a chain of separate but closely contiguous areas, which extends for 8

[1] Geological Survey of California, Vol. I, Geology, 1865, pp. 243–246.

[2] Auriferous Gravels of the Sierra Nevada: Mem. Mus. Comp. Zool. Harvard Coll., Vol. VI, 1880, pp. 131–137.

[3] Geology of California, 1865, p. 244, fig. 36.

Digitized by Google

miles along the west bank of the Stanislaus, regularly gaining in elevation, until the base of the flow at the end of this distance has an altitude of 3,000 feet above the sea and about 1,800 feet above the bed of the Stanislaus, giving a grade of about 125 feet to the mile.

Along this 8 miles the Table Mountain latite reposes upon a variety of underlying rocks. At the southern end, near Parrott Ferry, it rests upon granite. About three-quarters of a mile farther north the underlying rock is a limestone, belonging to the Calaveras formation.[1] The chief evidence for regarding this limestone as of Carboniferous age is the occurrence of Fusulina at Hites Cove.[2] A portion of the lava also rests upon the nearly vertical edges of a lenticular area of quartzose Calaveras schists inclosed in the limestone. Between the latite and the schists is a thin layer of breccia made up of fragments of the underlying schist. Still farther north the third area shown on the map is separated from the limestone by a thick deposit of auriferous gravel. Due east of the town of Vallecito the latite rests upon a bed of white rhyolitic tuff 200 feet in thickness, which in turn rests upon gravels. The rhyolite, although very plainly a tuff, is frequently divided into small columns by a rather regular prismatic parting. In one case where these columns were measured they were found to average 4 or 5 inches in diameter and about a foot in length between the joints. Columnar structure in tuffs, while not common, is not unknown. Moderni, as cited by Washington,[3] describes a columnar trachytic tuff in the Bolsena region.

To the east and southeast of Douglas Flat the relation of the latite flow to the ordinary andesitic breccia of the region and to the rhyolitic tuff is very interesting. The main ridge which separates Douglas Flat from the canyon of the Stanislaus is made up chiefly of andesitic breccia in a succession of nearly horizontal beds of great aggregate thickness, in places at least 700 feet, resting sometimes on the Bed-rock series and sometimes on an underlying bed of rhyolitic tuff. The latite flow occurs, not as a rule on the crest of this breccia ridge, but on its eastern side, overlooking the deep canyon of the Stanislaus, in characteristic flat-topped benches. These thin out on the west and overlap unconformably upon the andesitic breccia, while on the east they are terminated abruptly by perpendicular cliffs, frequently over 200 feet high, from whose edges are obtained grand views into the canyon below. At the base of these cliffs there is a bed of white columnar rhyolitic tuff, which appears to be at least 100 feet in thickness, and beneath this again a bed of auriferous gravel, varying in thickness and sometimes locally lacking. By a rather curious coincidence these benches of latite hang upon the slope at just the proper altitude to conceal the base of the andesitic breccia upon which they partly rest, the latter not appearing at the bottom of the cliffs at any point visited.

[1] See Gold Belt folios; also Lindgren, Am. Jour. Sci., 4th series, Vol. III, 1897, p. 302.

[2] Turner, Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 446; also Seventeenth Ann. Rept., Part I, 1896, p. 660.

[3] Italian petrological sketches: Jour. Geol., Vol. IV, 1896, p. 543.

Digitized by Google

From the northern end of this chain of dissected areas there is a gap of 3 miles before another remnant of latite is met with, capping a small hill just south of Mill Creek. The structure of this hill is rather complicated. On its western side the massive augite-latite is separated from the Bed-rock series by three beds of soft, light-colored tuff, while on the eastern side the place of the tuffs is taken by a sheet of gray, highly glassy lava with a pitchstone-like luster, which has been found to be a vitrophyric biotite-latite, somewhat resembling petrographically certain facies of the biotite-augite-latite forming the second flow of the series, and which is generally found resting *upon* the Table Mountain flow when the two lavas occur together. Chemical evidence seems to indicate, however, that it is perhaps a remnant of a distinct and earlier flow which preceded the Table Mountain flow.

Between the vitrophyric lava and the augite-latite cap occurs a very thin layer of reddish lava, of somewhat uncertain affinities, which has been found at only one other point, near Clover Meadow, and is there apparently beneath the Table Mountain flow. There is thus an indication that the long Table Mountain flow was not really the first of the latitic eruptions, but may have been preceded by a vitrophyric lava very similar to the biotite-augite-latite which preceded the Dardanelle flow. The field studied, however, affords no certain evidence on this point, and it must be left as a possible contingency that may meet with confirmation or denial when the geology of the Dardanelles quadrangle is fully investigated.

Immediately to the north of Mill Creek there is a small mass of the vitrophyric lava hanging upon the slope of a small spur overlooking the Stanislaus. It is evidently a continuation of the fragment south of Mill Creek, but here occurs alone, resting upon the edges of the Calaveras quartzite.

Following up the western bank of the North Fork of the Stanislaus, a small remnant of the Table Mountain flow is found about a mile and a half east of Manuel's, perched on the brink of the canyon at an elevation of about 3,200 feet and resting immediately on the granite.

A quarter of a mile farther upstream an interesting portion of the flow is encountered, which extends along the river almost continuously for 3½ miles to Squaw Hollow. The comparatively shallow drainage area of Love Creek is separated along this distance from the deeper canyon of the North Stanislaus by an even, flat-topped ridge, capped for the greater part of its length by andesitic tuff and breccia. The Table Mountain flow not only occupies the greater part of the valley of Love Creek, but also forms a distinct bench on the river side of the ridge, just below its crest. The outer edge of this bench is nearly always a vertical cliff, and the latite can generally be seen resting upon the granite. The relation to the andesitic breccia at the rear of the terrace is not easily determined. It is not always plain whether the andesite breccia is the later and rests upon the latite, as the mapping at first sight suggests, or whether the latter is really the younger rock,

Digitized by Google

which, having flowed down a channel cut through the breccia, has by a curious coincidence left its remnants lying unconformably upon both granite and breccia in such a way as to conceal their contact. In spite of its inherent improbability, there are indications which point to the latter hypothesis as the true one, especially as a similar relationship was observed east of Douglas Flat. That such a condition does obtain only a short distance away is shown at a point 1⅛ miles south of Squaw Hollow. (Pl. IV.) Here the nearly horizontal beds of light-gray andesitic breccia, with an aggregate thickness of 700 feet, are well exposed in a steep, bare slope, the lowermost bed reposing on the granite. The base of the Table Mountain flow is also very well exposed, and can be seen resting in striking uncomformity upon the eroded edges of the horizontal breccia beds, the plane of contact sloping down toward the river at an angle of about 20 or 25 degrees. The bottom of the flow is separated from the breccia by a thin layer of andesitic rubble or conglomerate, evidently derived from the underlying beds. Above this somewhat angular conglomerate comes the vesicular and more or less brecciated under surface of the massive latitic flow, passing, a little higher up, into a horizontally platy structure, which in turn is succeeded by a rude columnar parting. Although the base of the flow slopes down toward the bottom of the canyon at a considerable angle, its upper surface is more nearly level and forms a gently sloping bench, which breaks off abruptly toward the river in cliffs from 100 to 150 feet in height.

There is thus proof at this point, not only that the Table Mountain flow rests unconformably above a considerable thickness of the andesitic breccias, but that, at the time of its extrusion, the latter beds had been extensively eroded and a channel cut in them, which, here at least, was closely coincident with, though not so deep as, the present canyon of the North Stanislaus.

Near the crest of the ridge the Table Mountain flow becomes quite thin, and is overlain by biotite-augite-latite about 100 feet in thickness, which in turn is capped by about 75 feet of augite-latite, here occupying the summit of the ridge. This upper flow is lithologically nearly identical with the Table Mountain flow, but has somewhat smaller plagioclase phenocrysts, and on account of its position is correlated with the Dardanelle flow. The biotite-augite-latite occurs in three other places on the river slope of the ridge, in every case in small patches resting upon thicker masses of the Table Mountain flow. It is best seen, however, to the west of the ridge, in the little valley of Love Creek.

A few yards east of McKay's mill the attention is arrested by a low, gently arching lobe of dark-gray lava, which rises from the narrow floor of the valley with so clean and bare a surface that it appears to have been erupted within historical times. Its surface shows no sign of weathering, and is divided by cracks into rough polygonal blocks from

Digitized by Google

TABLE MOUNTAIN FLOW RESTING UNCONFORMABLY UPON BEDS OF FRAGMENTAL ANDESITE SOUTH OF SQUAW HOLLOW.

The view is taken from the east. The steep, bare slope in the foreground is andesitic breccia in nearly horizontal beds, upon whose edges the rudely columnar augite-latite can be seen resting in the upper left-hand portion of the illustration.

Digitized by Google

Digitized by Google

a foot to 2 feet in diameter. The rock cleaves most readily transverse to these rude vertical columns, the cleavage faces showing the characteristically abundant, glistening biotite crystals of the biotite-augite-latite. Upstream from McKay's mill the latite is found to fill most of the bottom of the little canyon, with a final isolated patch resting in the col at its head. As the ravine itself is excavated in granite, it is evident that it must have existed in substantially its present shape before the lava flow took possession of its stream bed. In other words, it is a remnant of a small Neocene valley. This result is startling when it is remembered that the main Stanislaus River has cut a gorge 1,000 feet deep directly across the Table Mountain flow upon which a portion of this biotite-augite-latite rests, while near Sonora the waste of the surrounding country has been sufficient to leave the same flow as a mountain mass, conspicuous for miles around. But, startling as it appears, there seems to be no avoidance of the conclusion here drawn. This survival explains why the old peneplain character is better preserved in this portion of the Sierra slope than in the foothill region; the rocks are more homogeneous and resistant, and the active erosion is largely concentrated in the deep canyon-cutting of the longer and more vigorous streams. This phase of denudation, although productive of striking results, is least calculated to obscure the peneplain character of the surface upon which it acts. It is quite probable that the present small stream of Love Creek has had its cutting power greatly decreased by the capture of its former head-water drainage by the deepening and widening of the North Stanislaus Canyon.

Near Squaw Hollow the line of the flow turns eastward and crosses the present canyon of the North Fork of the Stanislaus, another obvious instance of deep cutting since the eruption of the lavas. This canyon is not to be compared to that of the Middle Stanislaus, but some idea of its depth and the steepness of its walls may be gained when it is stated that the trail connecting the two groves of mammoth trees crosses at this point on a narrow bridge, and a horseman must travel more than 12 miles in a straight line up or down the stream before coming to another practicable crossing.

Two miles east of Squaw Hollow a remnant of the Table Mountain flow occurs resting upon a ridge of granite and surmounted by a small patch of the biotite-augite-latite. Another fragment occurs on the same ridge a little farther east. From these small areas there is a considerable gap in the continuity of the lava flows, until they are met with again, some 3 miles to the east, in the upper drainage of Griswold Creek. The most interesting occurrence here is about 1¼ miles south of Fennessy Meadow, on the divide between Griswold and Skull creeks, where a portion of the biotite-augite-latite can be plainly seen resting upon the andesite breccia, and in turn covered by a second bed of the latter. The volcanic rocks at this point cap a small elliptical hill and rest upon the basal granite of the region. At the eastern end

Digitized by Google

of the hill the latite is about 40 feet thick, and well exposed on the southern side, resting upon the breccia. Above the latite is a bed of soft, light-colored tuff, about 15 feet thick, which in turn is overlain by the ordinary andesitic breccia which caps the hill. At the west end of the hill a similar sequence is exposed, only here the latite is not more than about 25 feet thick, and rests directly upon the granite. Just to the east of the hill is a strip of augite-latite which appears to underlie the biotite-augite-latite, but the relation is not clearly shown. Other considerable masses of augite latite occur on Griswold Creek above Fennessy Meadow, but they were somewhat hastily examined, and it is not known whether they should be correlated with the Table Mountain flow or with the Dardanelle flow.

Near the head waters of Beaver Creek the andesitic breccia surrounds an area of granite, portions of which are higher than the bottom of the breccia, indicating a considerable irregularity in the old peneplain at this place. The biotite-augite-latite occurs at three points about the edge of this inclosed area, resting on the granite at the base of the breccia, and apparently overlain by the latter. The southernmost of the three patches is overlain by a portion of the Dardanelle flow.

The line of the latitic flows crosses the main breccia ridge at this point and appears on its eastern side in the drainage area of the Middle Stanislaus. Whether the flows are really continuous under a portion of the andesitic breccias is a question that was not determined with absolute certainty. The mapping indicates such a continuance, and the hypothesis is strengthened by the fact that on the eastern side of the ridge a portion of the sloping terrace formed by the Dardanelle flow and the underlying biotite-augite-latite is occupied by a small meadow, with strong springs issuing from beneath the andesitic breccia at its rear. As such springs are not common along the sides of these ridges, save where the porous breccia beds rest upon an impervious foundation, the presumption is that the massive Dardanelle flow here passes beneath a portion of the clastic series.

To the south and east of Clover Meadow the latites are well exposed. They occupy in general the crest of the ridge already described as running eastward toward the Dardanelles, and rest with evident unconformity upon the andesitic breccias and tuffs, or directly upon the granite, as seen about a mile to the south of Clover Meadow. All three of the flows are represented on the ridge. The earliest or Table Mountain flow is the most extensive, and rests upon a rather uneven surface of the clastic andesites. It varies greatly in thickness from point to point, and has a warped and twisted surface, rendering its mapping difficult on a small scale. At the western end of the ridge, about half a mile due east of the small pond in Clover Meadow, occurs an insignificant patch of the red lava, identical with that found south of Mill Creek, and occupying a position below and apparently geologically beneath the Table Mountain flow. Near the

Digitized by Google

CONTACT BETWEEN THE MASSIVE LATITE OF THE TABLE MOUNTAIN FLOW AND THE UNDERLYING ANDESITIC BRECCIA 1½ MILES EAST OF CLOVER MEADOW.

Digitized by Google

Digitized by Google

eastern end of the ridge the contact of the latite with the clastic andesite is finely shown (Pl. V). The lower portion of the massive flow is usually highly vesicular, and at the point shown in the illustration there is a cavity about 3 feet in height in the under side of the flow, its interior being lined with exceedingly frothy lava. At a short distance from the bottom the latite becomes less vesicular and takes on the usual platy structure, passing with increasing thickness into columnar parting. The character of the underlying andesite at this place is shown in Pl. VI. The material shows a rude stratification and the fragments are rounded or subangular, indicating that they were water deposited.

As already noted, the eastern end of the ridge falls off abruptly in a high bluff, in which are exposed over 400 feet of nearly horizontal beds, composed of andesitic sands and gravels partly consolidated. They form a part of the andesitic tuff series, but are somewhat more water-worn and better stratified than usual in this region. (Pl. VII.) The craggy masses in the upper right-hand corner of the illustration are composed of an andesitic breccia, which lies at a considerable angle and unconformably upon the stratified andesitic beds and underlies the Table Mountain flow. It appears to belong to the period of latitic eruptions, and to have immediately preceded the first of these. It has very little horizontal persistence, but is probably the equivalent of the conglomerate noted in a similar position beneath the lower latite flow, east of McKay's mill.

At the western end of a little meadow lying on the crest of the ridge, near its eastern end, the Table Mountain flow exhibits the interesting rounded forms shown in Pl. VIII. These recall certain spheroidal structures occurring in the Mesozoic basalts at Point Bonita,[1] in the Coast Ranges, although they are not so perfect as the latter. They are clearly not due to weathering and exfoliation, as the surface shown is perfectly bare of soil and exhibits only the merest traces of superficial decomposition. It is undoubtedly a structure produced during the cooling of the molten mass, and is replaced a few yards away by the ordinary columnar structure (Pl. IX). The surface shown in the illustration, Pl. VIII, is probably but little different from that of the original flow, and exhibits well its locally rolling character. That the ice at one time surmounted the ridge is indicated by the granitic bowlders which occur perched here and there upon the lavas, but it does not appear to have acted as an effective eroding agent.

At various places on the ridge the biotite-augite-latite rests upon the Table Mountain flow with an average thickness of something less than 50 feet, while on top of it again are masses of the Dardanelle flow, with an observed thickness of 100 feet. This latter rock generally shows a smaller columnar structure than the Table Mountain flow, the columns being rarely a foot in diameter and usually short and irregular.

[1] Univ. of Calif., Dept. Geol., Bull., Vol. I., 1893-96, pp. 71-114.

Digitized by Google

Probably no known area in the Sierra Nevada presents a more interesting succession of volcanic rocks than the cluster of peaks known as the Dardanelles. As a whole they have never been closely studied, and the present information has been derived merely from a short reconnaissance of the western peak, and an ascent to its summit. This peak is made up of a series of volcanic flows resting upon the granite as a basement, at an elevation of about 7,500 feet above sea. On the west side (the side shown in Pl. III) the lower member of the volcanic series is composed of several flows of olivine-basalt, aggregating from 500 to 600 feet in thickness. This basalt has suffered greater decomposition than the latites, and forms a steep, weathered slope, leading up to the base of the lofty cliffs which give the peak its striking outline. That the rocks composing this slope are true surface flows is indicated by the frequent vesicular and amygdaloidal bands from 10 to 40 feet in thickness, which are exposed in the small gullies channeling the weathered rock. The vesicles are usually lined with zeolites in the form of thin incrustations.

Resting sometimes directly upon the olivine-basalt, sometimes separated from it merely by a thin layer of volcanic conglomerate, is a thick mass of dark, columnar augite-latite, forming a vertical cliff over 400 feet in height. The lower 25 or 30 feet of the cliff face shows a very vesicular facies, becoming compact and columnar higher up. A short distance away from the mountain it could be seen that the columns became much larger some distance up the cliff, but it was not possible to determine whether this difference in size was significant of any division into an upper and lower flow, or whether the whole cliff face consisted of the Table Mountain flow. Hand specimens from the base of the cliff show a facies much like the typical Dardanelle flow, while fragments fallen from the upper portions exhibit the thoroughly characteristic features of the Table Mountain facies. The difference, however, is not greater than might easily obtain between the middle and basal portions of a single thick flow.

The conglomerate, mentioned as occurring between the olivine-basalt and the base of the latite, is composed chiefly of waterworn volcanic pebbles, some of which are identical with the underlying basalt, while others appear to be andesitic, or possibly latitic, in character. The bed is a lenticular one, about 12 feet in thickness and of small lateral extent.

Rhyolitic material was not observed on the west side of the peak, but an area of massive rhyolite is shown on the map just west of the peak and crossed by the trail going down to Highland Creek. This is the only area of undoubtedly massive rhyolite met with in the district embraced by the map. It rests immediately upon the granite, and, like the rhyolitic tuff of the region, is probably older than the andesites and latites.

Above the heavy columnar Table Mountain flow, and forming the extreme summits of the West Dardanelle, some rounded, dumpling-

Digitized by Google

ANDESITIC CONGLOMERATE UNDERLYING TABLE MOUNTAIN FLOW 1¼ MILES EAST OF CLOVER MEADOW.

The illustration shows the imperfect rounding of the volcanic fragments and the rude stratification of the whole. These are outlying pinnacles left by differential erosion upon the steep hill slope.

Digitized by Google

Digitized by Google

shaped masses could be seen, which the glass showed to have the smaller columnar structure generally associated with the uppermost, or Dardanelle flow.

On the southeast side the ascent to the top of the peak is not difficult. It was found that the lowermost member of the volcanic series on this side is a rhyolitic tuff, inclosing foreign waterworn pebbles, and about 50 feet thick, probably resting on the granite, although the base was not seen. Above the tuff the same olivine-basalt already mentioned is exposed for a thickness of 150 feet. The succeeding 300 feet of vertical elevation is occupied by a very rough talus slope, composed of fallen columns from the cliffs above, which on this side show a height of nearly 500 feet by aneroid barometer. The lower 200 feet of the cliff exposed is coarsely and somewhat irregularly columnar; toward the top this passes gradually into a zone characterized by a horizontally platy structure, which in turn is succeeded by an irregularly jointed and vesicular upper portion, becoming a flow breccia at the extreme top. No evidence was found on this side of the mountain to indicate that this thickness of 500 feet is made up of any more than the single Table Mountain flow. Its bottom, however, was not seen.

On the top of this thick flow, exposed in the saddles between the three summits shown on the map, lies the biotite-augite-latite of the second flow, here 50 feet in thickness.

The summits themselves are composed of remnants of the Dardanelle flow, which on the western knob has a thickness of at least 160 feet. It shows the usual small columns and fresh bare surface, its dissection being due rather to an undermining and falling away of the columns than to its own weathering. The entire thickness of the latites here exposed is at least 710 feet, and of the entire volcanic accumulation above the granite 1,210 feet. These figures, however, are from aneroid readings, while the topographical map would indicate a total thickness of 1,400 feet. It is noteworthy that this thickness does not include any of the ordinary andesitic breccia which elsewhere occurs in such volume beneath the latites.

The Dardanelle Cone, 9,529 feet, the highest peak of the group, was not visited. It owes its name to its sharp conical summit as seen from the west, but, like the West Dardanelle, appears to be made up of horizontal volcanic rocks resting upon the granite. The lower beds are light in color, suggesting rhyolitic or andesitic tuffs.

The view from the summit of the West Dardanelle is in many ways an exceedingly interesting one. In the immediate foreground, to the west and north, lies a broad basin of bare, glaciated granite, rounded and polished by the ice, and dotted here and there with lakes or grassy meadows. To the south lies the gorge of the Middle Stanislaus—too deep and narrow for its bottom to be seen, even from such a vantage point. But if the eyes are withdrawn from what lies just below them and allowed to sweep the horizon, the attention is at once attracted by

Digitized by Google

the several peaks of similar structure to that upon which the observer stands; that is, they are made up of nearly horizontal flows or breccia beds, resting upon a granitic basement. Not only are they of similar structure, but they stand with their tops close to an imaginary plane having a noticeable slope to the southwest, the general western slope of the range, which is rendered more apparent when seen from so high an altitude. Toward the west the ridges are lower, and, as has been shown, are composed in part of the same latitic flows. To the east and northeast they are higher and less continuous, being frequently isolated peaks, and less is known of the nature of their volcanic caps. It is probable that they are in part composed of latite, as Whitney[1] mentions the occurrence of lava similar to the Table Mountain flow south of Hermit Valley. But they are probably largely made up of the ordinary andesitic breccia of the range.[2] This appears to be especially true of the ridges to the southeast across the main Stanislaus River. It is evident that in Tertiary times this portion of the range was a peneplain, or a surface of comparatively gentle relief, which at the end of the Neocene was covered by volcanic tuffs and flows. Moreover, the latite now crowning the Dardanelles can not mark the upper limit of this accumulation, for, as has been shown in the preceding pages, these lavas flowed down channels in the andesite, and were in turn covered by fresh accumulations of the same breccia. The only remnants of all this volcanic covering now visible from the summit of the West Dardanelle are a few residual peaks and ridges which, owing to a more resistant capping, or to other causes, have survived the general degradation. The picture of profound denudation, shown in the uncovering of the old granite surface and its deep trenching by such streams as the Stanislaus, would be impressive in any case, but it becomes doubly so when it is remembered that all this has taken place in post-Tertiary times.

Thus far the latitic lavas have been described as if they were confined in their distribution to the main line of flow outlined in the preceding pages. But this is not entirely the case. As shown on the accompanying map, the biotite-augite-latite occurs in small isolated areas at considerable distances from the main flow-axis, even appearing in the drainage area of the Mokelumne River, to the north of the Stanislaus Basin. It is possible that there may be a few more of these patches than have been indicated, as they frequently occur very unobtrusively near the contact of the andesite breccias with the underlying granite, and are often concealed in the heavy timber. In such situations it is generally impossible to determine positively whether the latite really underlies the andesite or vice versa. South of the Middle Stanislaus are several small areas of the biotite-augite-latite which plainly rest upon the andesitic breccias and tuffs, in most cases with evident uncon-

[1] Auriferous Gravels, 1880, p. 131.

[2] See Turner, Geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, pp. 708–709, for some interesting notes on this region, with views of the andesite breccia (Pl. XXXVI).

Digitized by Google

VIEW OF BLUFF WHICH TERMINATES THE RIDGE ABOUT 2 MILES EAST OF CLOVER MEADOW, SHOWING THE STRATIFICATION OF THE ANDESITIC BEDS.

The pinnacles on the left are composed of a coarse andesitic breccia resting unconformably upon the stratified tuffs and conglomerates and underlying the Table Mountain latite, which is not shown.

Digitized by Google

Digitized by Google

formity. This relation is well shown about 2 miles southeast of Mount Knight, where the latite, beginning with a point on the top of the ridge overlooking the Middle Stanislaus, runs obliquely down over the beveled edges of the nearly horizontal clastic andesite, resting finally on the schists of the Bed-rock series just above Rose Creek.

As will be seen in the section devoted to the petrography of the latites, the biotite-augite-latite has characteristics that render its distinction from a tuff not always easy. The fact that it has a wider distribution than the two undoubted massive flows, also suggests that it may have had a different origin. But the field evidence does not support the view that it is in any sense a water-deposited tuff. It is entirely devoid of the horizontal bedding characteristic of the known tuffs of the region, and on the other hand it possesses the more or less uneven upper and lower surfaces, and the ability to lie upon perceptible slopes, which are characteristic of true lava streams. It also resembles lavas in being coarsely columnar in structure, although, as has been shown, this structure may also occur in undoubted tuffs. The basal contact of the biotite-augite-latite was nowhere seen sufficiently well exposed to give a decisive answer to the question whether it is tuffaceous or massive in character.

PETROGRAPHY OF THE LATITES AND OF THE OTHER VOLCANIC ROCKS ASSOCIATED WITH THEM.

As frequently emphasized in the preceding account of its distribution, the lava composing the Table Mountain and Dardanelle flows is dark in color and basaltic in general appearance. The earlier writers, without exception, referred to it as basalt, and until very recently no reason had appeared for revising their determination. In 1895, however, Turner wrote as follows:

> The basalt of the Tuolumne Table Mountain is also a dark, heavy rock, but as may be noted below [referring to an accompanying chemical analysis] has an unusually high percentage of silica for a basalt. It is also characterized macroscopically by containing numerous cavities and tabular porphyritic feldspars which are sometimes half an inch long.[1]

In a later paper, published after the field seasons of 1895 and 1896, occurs the following paragraph:

> Tertiary trachytes are known thus far only in the area of the Big Trees sheet. They occur both as tuffs (?) and massive flows, the latter strongly resembling basalt in macroscopic appearance. They are placed with the trachytes chiefly on the basis of their chemical composition. Indeed, the Tuolumne Table Mountain basalt has so high an alkali content that it is placed in the table with the trachytes for comparison. This flow can be traced from Knights Ferry, in Stanislaus County, across the Sonora area into the Big Trees district, not far from where specimens 85 and 86 Tuolumne were collected. As the writer has only cursorily examined these trachytes, the matter of their classification will not be further considered at present.[2]

[1] Rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 491.

[2] Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 729.

Digitized by Google

By way of preliminary explanation, it may be stated that both the "trachytes" and the "basalt" referred to in the foregoing citation are portions of the latitic flows which form the subject of the present paper. This separation into trachyte and basalt, it will appear, was not without excuse so long as hand specimens from somewhat widely separated localities were made the basis for such distinction, and the mere fact that lavas belonging to one chemical and mineralogical type, if not, in some cases, to one flow, could be tentatively classed as trachytes in one place and basalts in another, is not without its bearing on the question of their proper classification.

THE TABLE MOUNTAIN FLOW.

Megascopically the Table Mountain latite shows great uniformity, from the end of the flow, near Knights Ferry, to the Dardanelles, the highest point at which it has been studied. It may become locally vesicular, especially at the top and bottom of the flow, or show slight variations in the number and size of the phenocrysts, but in general the description of any one hand specimen will apply with but slight modification to any portion of the 60 miles of flow.

A specimen (1820 S. N.) from just west of Parrott Ferry, at the point where the river has cut its gorge across the line of the lava stream, may be considered as typical. This is a dark rock, of compact texture and basaltic aspect, characterized by an abundance of large glassy plagioclase phenocrysts lying in a dense, nearly black groundmass. The plagioclases are tabular parallel to the brachypinacoidal faces, a common size being about 2 mm in thickness, 8 mm in breadth, and 10 mm in length. A length of 15 mm may, however, be frequently observed. The cleavage faces, on the freshly fractured rock surfaces, always show twinning according to the albite law, and not infrequently an additional twinning following the Carlsbad law. Dark olive-green augite can be distinguished in the form of phenocrysts, but it is neither an abundant nor a conspicuous constituent as compared with the plagioclases. The rock is somewhat vesicular, the vesicles being usually elongated in the direction of flow, and occasionally filled with calcite.

Under the microscope the large plagioclase crystals are by far the most conspicuous mineral in the slide. Augite is much less abundant, but occurs in phenocrysts of considerable size and usually of irregular outlines. Olivine is moderately abundant in small, more or less idiomorphic phenocrysts up to 0.5 mm in length. The groundmass is hyalopilitic.

The large plagioclases generally show approximate crystallographic outlines, but they are often rounded and sometimes deeply embayed. Although perfectly fresh, they are apt to be crowded with inclusions of dark, glassy base, giving them a mottled appearance not unlike the

Digitized by Google

SPHEROIDAL FACIES OF AUGITE-LATITE OF THE TABLE MOUNTAIN FLOW.
At the western end of a little meadow on the crest of the ridge, about 1¼ miles east of Clover Meadow.

Digitized by Google

Digitized by Google

crystal figured by Rosenbusch[1] from a Hungarian augite-andesite. They are invariably twinned in accordance with the albite law, but the resulting lamellæ are of very different widths, ranging from those just visible up to 0.5 mm or over. The frequent combination of Carlsbad with albite twins renders the determination of the feldspars by Michel Lévy's method comparatively easy. In a section at right angles to the plane of the brachypinacoid, angles of extinction were obtained on each half of the Carlsbad twin of 14.5° and 33.5°, indicating a labradorite with about the composition Ab_3An_4. A section cut approximately parallel to the brachypinacoid and revealing no twinning showed the emergence of a slightly oblique acute bisectrix and gave an extinction angle of about 16° with the basal cleavage, the angle varying somewhat for different portions of the crystal.

Pericline lamellæ are occasionally observed in conjunction with the albite twinning.

An attempt was made to determine the specific gravity of the plagioclase phenocrysts by suspending fragments in Thoulet solution. Some very small and apparently pure grains neither floated nor sank at 2.684, but the specific gravity of particles over a millimeter in diameter was found to be about 2.651. The latter figure is undoubtedly lower than the true specific gravity of the feldspar, as it is impossible to secure fragments that are free from inclusions and yet large enough to give satisfactory determinations by suspension in a heavy liquid.

The augite phenocrysts are generally irregular and rounded in outline, but are sometimes crystallographically bounded in the prism zone. They are very pale green in color, nonpleochroic, and resemble diopside; but the extinction angle on *c* is often over 40°, and sometimes as high as 45°, and they are more properly classed as pale augite. As Zirkel[2] points out, such pale-green augites are characteristic of rocks high in alkalies, while brownish augites are more common in basalts.

The olivine, like the other minerals in the slide, is perfectly fresh, and forms small crystals, usually less than 0.5 mm in length, and showing slightly rounded crystallographic outlines. Although occurring in much smaller crystals than the augite, it appears to be nearly as abundant in the thin section, and may be regarded as an essential constituent of the rock.

The groundmass, from which the phenocrysts are distinctly differentiated, shows a rather coarse hyalopilitic structure, made up of feldspar microlites, grains of magnetite, augite, olivine, and glass. Structurally, it is very similar to the olivine weiselbergite of Rosenbusch,[3] as seen in one of Voigt and Hochgesang's thin sections. The feldspar microlites usually show distinct albite lamellæ, which extinguish at considerable angles, indicating a labradorite but little, if any, less basic than the phenocrysts. As one of the distinctive characters of the latites

[1] Mikroskopische Physiographie (3d ed.), Vol. I, 1892, Pl. XXIV, fig. 3.
[2] Lehrbuch der Petrographie, 2d ed., Vol. I, 1893, p. 281.
[3] Op. cit., Vol. II, 1896, p. 954.

Digitized by Google

described in this paper is their relatively high potash content, and as Washington[1] has described orthoclase in rocks of almost identical chemical composition from Italy and Asia Minor, pains were taken to determine whether any of the microlites were potash feldspars. But microscopical study gives no ground for believing that any other feldspar than labradorite is present. Some of the labradorite phenocrysts were observed to be bordered by an extremely narrow zone of more acid feldspar—possibly orthoclase. This, however, is not common.

The glassy portion of the groundmass appears to make up less than half its bulk. It is light brown in color, and quite turbid from the presence of very minute globulites. The magnetite occurs in small but distinct grains, rather abundantly and evenly distributed through the section. The olivine and augite grains in the groundmass differ in no way but in their small size from the same minerals in the phenocrysts, and are not to be sharply differentiated from the latter. The olivine frequently occurs as inclusions in the augite, and the latter is sometimes included in the large labradorite phenocrysts. Apatite occurs in small prisms, commonly included in the augite.

Turner[2] has given a microscopical description of a specimen (36 S. N.) collected from Table Mountain near Shaws Flat. He says:

> Microscopically the Table Mountain basalt shows large tabular feldspars, smaller augites, and numerous olivine grains in a nearly opaque groundmass, in which are very abundant feldspar microlites. This groundmass doubtless contains a large amount of magnetite, and strongly resembles some of the sections of the older basalt. There is a good deal of brownish serpentinoid substance in the groundmass. The porphyritic feldspars are polysynthetically twinned and have a corroded appearance, due to the abundant inclusions of aggregates of opaque particles, with some glass inclusions. There is also some serpentine in the large feldspars.

An analysis of this specimen is appended to his description and has been quoted in Column I of the table of chemical analyses on page 58.

Mr. Turner having kindly allowed me to examine two thin sections of this rock, it was found that it differed from most of the specimens collected at other points along the Table Mountain in the slightly greater abundance of the olivine, in the presence of the serpentinous patches, and in a rather unusual opacity in the glassy base. A single rounded crystal of slightly pleochroic orthorhombic pyroxene was noted included within a large augite phenocryst, but this mineral is very rare in the Table Mountain flow. The groundmass is hyalopilitic. The opacity of the groundmass is seen with high powers to be due to the dense crowding of minute globulites of rather peculiar character. These globulites occur also in the Dardanelle flow, and as they have been there more studied their description will be for the present deferred.

A specimen (1016 S. N.) taken on the trail passing over the top of

[1] Italian petrological sketches: Jour. Geol., Vol. IV, 1896, p. 547 *et seq.*, and On igneous rocks from Smyrna and Pergamon: Am. Jour. Sci., 4th series, Vol. III, 1897, pp. 41–50.

[2] Rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 491.

Digitized by Google

COLUMNAR FACIES OF THE AUGITE-LATITE OF THE TABLE MOUNTAIN FLOW.

About 1¼ mile east of Clover Meadow, on the crest of the ridge. The light-colored bowlders in the foreground and the larger masses on top of the lava columns are glacial erratics

Digitized by Google

Digitized by Google

the mountain between Sonora and Tuttletown is thoroughly typical and shows particularly well the numerous inclusions in the large labradorite phenocrysts. These inclusions are usually composed of globulitic glass, with microlites of labradorite and augite, and are similar to the fine groundmass of the rock.

Northeast from Parrott Ferry the Table Mountain flow was investigated microscopically at many points, with the general result of showing great structural and mineralogical uniformity. In general, as the flow is followed higher up into the mountains the olivine becomes somewhat less abundant and sinks to crystals of smaller dimensions. The large labradorite phenocrysts, while preserving their size and characteristic mottling, seem to become progressively slightly more acid, numerous determinations by the Michel Lévy method indicating that in the more eastern portions of the flow a labradorite of the approximate composition Ab_1An_1 predominates. Apatite is a constant accessory, occurring in the groundmass and in the augites.

About 1¼ miles southwest of Collyer's a facies (1845 S. N.) occurs in which the labradorite phenocrysts are somewhat smaller than usual, the rock standing megascopically about halfway between the normal Table Mountain facies and the usually finer-grained rocks of the third, or Dardanelle, flow. A thin section shows the usual phenocrysts of labradorite, augite, and olivine. The labradorites are twinned with beautiful sharpness and vary considerably in the number of inclusions contained within them. One long crystal of irregular shape was observed to be a veritable sponge, inclosing glass and microlites of plagioclase and augite. The groundmass is hyalopilitic and contains a little carbonate scattered through it.

A specimen (1945 S. N.) from the portion of the flow 1 mile northeast of McKay's mill, shown in Pl. IV, also has somewhat smaller plagioclase phenocrysts than usual, and resembles in megascopic character the Dardanelle flow, which lies above it, separated by the biotite-augite-latite. Under the microscope, however, it shows no marked difference from other thin sections from the same flow. There are the same large labradorites mottled with glassy inclusions and showing albite twinning lamellæ combined with those of the Carlsbad and pericline laws. Augite is present in large, irregular phenocrysts and in smaller crystals with idiomorphic cross sections transverse to the prism. Olivine is distinctly less abundant and occurs in smaller crystals than in that portion of the flow near Shaws Flat already described. In this particular slide it has been almost wholly altered to serpentine, a rather uncommon condition in the Table Mountain flow. The groundmass is finer, less opaque, and typically hyalopilitic.

Across the north fork of the Stanislaus the small area 1½ miles east of Squaw Hollow presents a thoroughly typical facies (1913 S. N.), both megascopically and microscopically. The large labradorites frequently show Carlsbad twins and give extinction angles corresponding to the

Digitized by Google

mixture Ab_3An_4. They sometimes show deep and intricate embayments, and are full of the usual inclusions. The augite occurs in characteristic phenocrysts and also as small grains, which are sometimes heaped together in a manner suggesting the aggregates formed by the magmatic resorption of hornblende in many andesites. Like the Shaws Flat facies described by Turner, the glassy base is dark and semiopaque, and the slide contains small irregular patches of greenish-yellow serpentine. The latter does not show definite outlines, and is not a pseudomorph after any crystalline mineral. It permeates portions of the slide irregularly, and may fill some small vesicles. Augite and olivine are less abundant than in the Shaws Flat rock, the latter mineral occurring only in small crystals in the groundmass.

The small mass (1794 S. N.) resting upon the andesitic breccia 2 miles northeast of Ashcraft's is megascopically halfway between the typical facies of the Table Mountain and Dardanelle flows. Under the microscope it shows an equally intermediate character, and may possibly belong to the latter flow. The labradorite (Ab_3An_4) phenocrysts are fresh and sharply twinned, pericline lamellæ being not uncommon. They show the basal and brachypinacoidal cleavages in systems of fine cracks, and are comparatively free from inclusions. The other phenocrysts are augite, magnetite, and olivine, lying in a hyalopilitic groundmass with considerable globulitic glass.

As the lava showing the spheroidal forms seen in Pl. VIII has been subjected to chemical analyses, it will be described somewhat at length. Megascopically the rock (1422 S. N.) forming these spheroids is indistinguishable from specimens collected from the Tuolumne Table Mountain, 40 miles to the southwest. It shows similar tabular phenocrysts of labradorite, with here and there an irregular crystal of augite, lying in a compact dark groundmass. The plagioclases are fresh and glassy, and their glistening cleavage planes are the most conspicuous features of the freshly broken rock, and even of the natural surfaces, for the weathering has been but skin deep. A common size for these phenocrysts is about 2 by 7 by 9 mm, the plane of greatest extension being the brachypinacoid. They invariably show the albite twinning on the basal cleavage planes, and not uncommonly Carlsbad twinning also.

Under the microscope the thin section (Pl. XI, *A*) shows the usual phenocrysts of labradorite and pale-greenish augite with small idiomorphic olivines, lying in a very fine, even groundmass, which is typically hyalopilitic, showing flow lines of the small lath-shaped microlites around the phenocrysts. The large labradorites show the usual rounded and embayed outlines, and are mottled with abundant inclusions. The latter are usually similar to the glassy base of the rock, but more rarely a greenish serpentinoid substance. Some of the labradorites have been broken in the magma and the parts displaced, and angular fragments, probably of similar origin, are common. The

Digitized by Google

VIEW OF THE DARDANELLES FROM A HIGH POINT TO THE SOUTH, LOOKING OVER THE CANYON OF THE MIDDLE STANISLAUS RIVER.
Photograph by H. W. Turner.

Digitized by Google

Digitized by Google

PLATE XI.

Digitized by Google

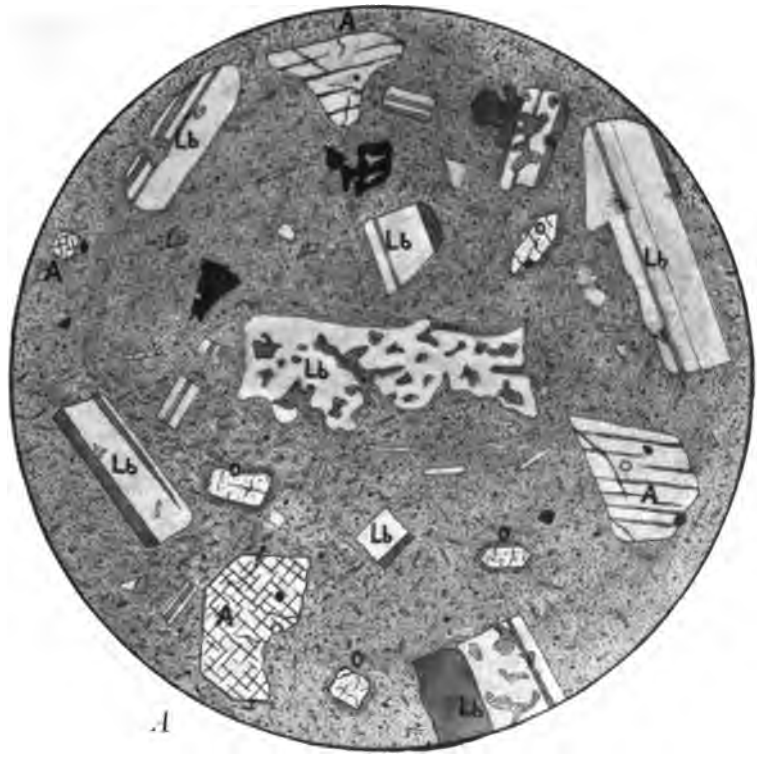
PLATE XI.

MICROSECTIONS OF LATITES (SEMIDIAGRAMMATIC).

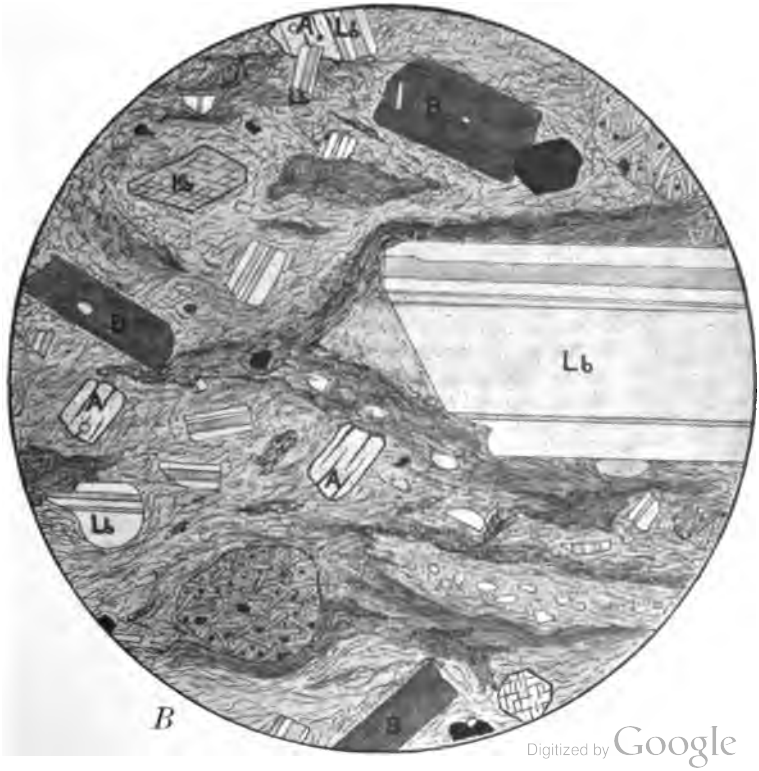
A. Augite-latite (1422 S. N.), Table Mountain flow, showing general structure of the rock, with phenocrysts of labradorite (Lb), augite (A), olivine (O), and magnetite.

B. Biotite-augite-latite (1955 S. N.), showing eutaxitic or "piperno" structure. The drawing shows phenocrysts of labradorite (Lb), augite (A), biotite (B), hornblende (Hb), and magnetite, with included rock fragments, lying in a banded and partially brecciated microlitic glass.

Digitized by Google



A



B

Digitized by Google

Digitized by Google

plagioclases show the usual combination of albite and Carlsbad twinning, with occasional pericline lamellæ. A determination of the extinction angles by Michel Lévy's method indicated a labradorite with the composition $Ab_1 An_1$. The specific gravity of a small, apparently pure fragment was found by means of Thoulet solution to be 2.648, which is rather light for apparently so basic a plagioclase. The augite, which is much less abundant than the labradorite, is very pale green in color, nonpleochroic, and identical with that already described. Sharply idiomorphic cross sections of the prism zone are rather more common than usual. It is frequently twinned polysynthetically on the orthopinacoid in the usual manner. The olivines are fairly abundant, but small. They are generally fresh, and show crystallographic outlines, but in somes cases they are changed to yellow serpentinous pseudomorphs. The groundmass around these olivine crystals is sometimes distinctly more finely crystalline than elsewhere, giving them the appearance of being surrounded by a faint halo. Some scattered crystals of magnetite are of sufficient size to be included among the phenocrysts.

The groundmass is truly hyalopilitic, and is made up of small slender feldspar microlites, minute crystals of magnetite, and globulites, all lying thickly crowded in a clear glass of faint brownish-violet tint. The microlites are often so crowded that it is difficult to find a portion of the section that will show no double refraction between crossed nicols. By using an immersion objective, however, and working on the thinnest edges of the section, it is possible to differentiate the glassy matrix from the feldspar microlites and to see that it is full of crystals of magnetite, ranging from those that show crystal outlines down to barely visible black specks. Associated with the magnetite grains are numerous globulites and globulitic granules of high relief and faint green tint, which are probably augite. From this it appears that magnetite, although not conspicuous with low powers, is yet quite abundant in the mass of the rock. Augite, also, is probably a more important constituent than would be indicated by its distinct crystals.

The feldspar microlites are generally too small to be determined optically, but the better-individualized ones generally show albite lamellæ with an obliquity of extinction corresponding to labradorite. Apatite occurs in rather stout, sharply hexagonal prisms.

A chemical analyses of this rock is given in Column III of the table of chemical analyses on page 58. Its specific gravity is 2.67, which is lower than one would usually expect in a rock of such dark color and compact texture.

A few hundred yards to the east of the spheroidal facies the bottom of the Table Mountain flow is exposed, resting upon clastic andesitic beds, as shown in Pl. V. The flow is here exceedingly vesicular in its lower portions, the large labradorite phenocrysts being held together by a paste of frothy red glass. The microscope shows the usual labra-

Digitized by Google

dorite phenocrysts full of glass inclusions. Augite was observed only as an inclusion in one of the labradorites. The cementing material is a vesicular, semiopaque brown glass, with a few labradorite microlites. The turbidity of the glass is apparently due to the oxidation of the magnetite, contingent upon the highly spongy character of the rock. The inclusions in the large plagioclases are of the same glassy nature as the matrix, while in other occurrences already described the inclusions consist of more or less individualized groundmass, thus indicating that crystallization went on in the included portions as well as in the groundmass outside the labradorite phenocrysts.

At the West Dardanelle the latite of the Table Mountain flow (1023 S. N.) is megascopically identical with the spheroidal facies (1422 S. N.) just described, although its larger structure is columnar. Microscopically it resembles rather more closely the sections from the Table Mountain near Sonora, although with considerably less olivine. The large labradorites give extinction angles corresponding to a mixture Ab_1An_1. They are full of inclusions of glass, with sometimes small crystals of augite and labradorite. The augite phenocrysts are larger and more abundant than usual. They are sometimes, like the labradorites, filled with inclusions, plagioclase laths and small patches of yellow serpentine being among the latter. The thin section also shows serpentinous patches like those described in the Tuolumne Table Mountain specimens. Olivine, however, is not so abundant, being confined to small idiomorphic crystals scattered through the groundmass. These are generally fresh, but are sometimes partly changed to serpentine.

A specimen (1030 S. N.) taken near the upper surface of the flow is rendered spongy by abundant small vesicles. Under the microscope it shows the same phenocrysts as the preceding rock, but the labradorite microlites in the groundmass are much smaller, and the rock as a whole is more glassy. With high power the glass is seen to be thickly dusted with magnetite and globulites and to show the faint violet-brown tint characteristic of the perfectly fresh glass of these rocks. In spite of the freshness of the other constituents, the olivine has all been altered to yellow serpentinous pseudomorphs.

The microscopic petrography of the Table Mountain flow has been described at some length on account of its interesting chemical character, and for the reason that such a course seemed desirable in dealing with a flow so greatly dissected. It is seen that in its superficial appearance and in the presence of olivine the augite-latite resembles the basalts; in the character of the augite and plagioclase, in the degree of preponderance of the feldspathic constituents, and in the hyalopilitic structure of the groundmass, it is more closely related to the andesites; lastly, in the fine dissemination of the magnetite, in the abundance of microtine phenocrysts, and, above all, in chemical composition, it shows certain analogies with the trachytes. No potash feldspar has been detected in any of the thin sections studied, except,

Digitized by Google

possibly, as a very narrow fringe on some of the labradorite phenocrysts, and even this seems to be the exception rather than the rule.

THE BIOTITE-AUGITE-LATITE.

As already indicated in the account of its occurrence, considerable difficulty was experienced in deciding whether this volcanic rock was a true flow, like the Dardanelle flow above it and the Table Mountain flow beneath it, or whether it should be classed as a tuff. In spite of the fact that it frequently shows the presence of fragmental material the rock is regarded as constituting a flow, for reasons that can be better appreciated after a petrographical description.

The facies occurring within the drainage of Love Creek, about 3 miles south of Big Trees post-office, is a thoroughly typical one. A specimen (1882 S. N.) taken just north of the road, about a mile southwest of McKay's, shows a bright-gray rock, that sparkles brilliantly on fresh surfaces, from the numerous crystals of biotite. In contrast to the Table Mountain augite-latite upon which it lies, this rock has a harsh or trachytic feel and is somewhat porous. Besides the biotites, the fine, and evidently glassy, groundmass holds small phenocrysts of clear sanidine-like feldspar and fragments of dark glass and of glassy volcanic rock. Some of the black glass inclusions are irregular and somewhat angular in outline, while others appear to be drawn out into thin lenses. These lenses, together with the biotite crystals, have a tendency to lie horizontal, so that the lava cleaves most readily along a plane parallel with the top and bottom of the flow. This arrangement is by no means universal, however, for the biotite tablets are found in all positions. These latter are from 1 to 2 ^{mm} in breadth and sometimes 0.5 ^{mm} in thickness. They have sharp crystallographic boundaries, the narrow planes of the prism and clinopinacoid reflecting the light nearly as brilliantly as the basal planes.

The thin section shows that the greater part of the rock is made up of a light-brown glass, with a suggestion of violet in its peculiar tint. Scattered about in this glassy matrix are abundant phenocrysts of plagioclase and biotite, a few broken or irregular crystals of augite, crystals of magnetite and apatite, and fragments of more or less glassy volcanic rocks.

The plagioclases usually show beautifully sharp twinning in accordance with the albite law, and some show both albite and Carlsbad twinning, with occasional pericline lamellæ. The Carlsbad-albite twins give extinction angles corresponding to labradorite of the composition Ab_3An_4. There is no sanidine present, and the index of refraction of all the plagioclase, as determined by Becke's method, is distinctly greater than the balsam of the slide, which is about 1.540. The outline of the plagioclases is sometimes irregular and angular, sometimes rounded, and sometimes in part defined by crystallographic planes.

The biotite is abundant and in sharply bounded hexagonal tablets.

Digitized by Google

It is bright chestnut brown, with the usual strong absorption and small axial angle. It frequently includes prisms of apatite.

Augite is not abundant, and rarely shows crystallographic outlines. It is very pale green, and in no way distinguishable from that in the Table Mountain flow, already described.

A green hornblende is quite charactistic of this rock, occurring in nearly every slide of the biotite-augite-latite, but always in strictly accessory amount. It is usually in small shreds or irregular fragments, of which not more than two or three are found in any single thin section. In only two cases were prismatic cross sections seen with anything like idiomorphic outline, the best of these being shown in Pl. XI, *B*. The optical orientation is: $\mathfrak{a} = a$, $\mathfrak{b} = b$, and $\mathfrak{c} : c =$ at least 11°. The pleochroism is: $\mathfrak{a}$, faint yellow; $\mathfrak{b}$, dark brownish green, and $\mathfrak{c}$, dark green. The absorption is: $\mathfrak{a} < \mathfrak{b} < \mathfrak{c}$.

Magnetite occurs in good-sized grains in the glass, sometimes attached to the anhedra of labradorite and augite, and frequently including prisms of apatite. The latter mineral also occurs isolated in the brown glass in well-developed prisms.

The sharply bounded rock inclusions, as seen in the slide, are usually of small size, less than 0.5 mm in diameter, and rounded in outline. They consist of fragments of andesitic or latitic groundmass, generally indistinguishable, in such small areas, from facies of Table Mountain and Dardanelle flows. They sometimes contain phenocrysts of labradorite like those occurring in the inclosing rock. The glass base of these inclusions is usually gray and globulitic, but sometimes clear and pale brown, like that making up the mass of the section. In one case a rounded inclusion was observed with a central portion composed of labradorite microlites and gray glassy base, and a peripheral zone of similar microlites lying in a clear, light-brown glass.

An examination of the isotropic matrix which makes up the mass of the rock shows it to be by no means homogeneous. It is a confused mixture of shreds and strings of light-brown, translucent glass, with other portions which are rendered dark and turbid by microlites and globulitic dust. Sometimes these lighter areas are sharply bounded and resemble inclusions, at other times they fray out imperceptibly into the groundmass, or are drawn out in long flamboyant tongues. Some of the light-brown patches contain plagioclase microlites, and such portions are not always sharply separated from the nonmicrolitic areas. The whole aspect of the thin section suggests that the development of a fluidal structure was followed by flow brecciation on a minute scale, giving as a result a rock that is in some respects not unlike a tuff. That the rock is not an ordinary tuff is indicated by the close affinity shown between the inclusions and the including matrix, by the absence of distinctly foreign material, by the inclusion within areas of homogeneous brown glass of labradorite phenocrysts exactly like those which occur in the finely brecciated portions, and, lastly, by inclusions of the same light-brown glass within such phenocrysts.

Digitized by Google

On the supposition that the rock, if a clastic tuff, must owe its present induration to the presence of a considerable proportion of opal among the isotropic material, a weighed portion of the finely powdered rock was boiled in a platinum dish for two hours with a 10 per cent solution of sodium carbonate. The dish was allowed to stand for nineteen hours, again heated, the liquid filtered off, and the silica determined in the usual way. The amount soluble under these conditions was only 1.6 per cent.

A specimen (1877, S. N.) from the coulée-like mass half a mile north of McKay's, already described, is slightly darker in color than the foregoing, and, while plainly containing inclusions, has every appearance, both in the field and in the hand specimen, of being a glassy lava and not a tuff.

At first glance the thin section looks tuffaceous, but closer examination shows that the shreds of violet-brown glass, instead of behaving as rigid clastic fragments, frequently curve around the phenocrysts and inclusions in well-marked flow lines, or conform to their shape. The glass has a rather more distinct violet tint in this section, and is a little more abundant, than in the one just described. There is also a little more augite. The specific gravity of the rock is 2.47.

One mile northeast of McKay's, on the river slope of the ridge, the biotite-augite-latite (1944 S. N.) resembles megascopically that first described (1882 S. N.), but shows many long-drawn-out lenses of dark glass. Under the microscope it shows comparatively few phenocrysts or inclusions and a large proportion of the faint violet-brown glass. One small fleck of green hornblende occurs in the slide.

The latite of the elliptical area (1977 S. N.) shown on the map 1¼ miles a little west of south from Fennessy's, and overlain by andesitic breccia and tuff, is light gray in color, with a somewhat more earthy texture than usual, and less biotite. Under the microscope it shows the usual characteristic features, although the biotite is not quite so abundant. There are a few fragments of the green hornblende present. The shreds of pale-brown glass show some flow structure and are bent around the phenocrysts and included fragments.

A specimen (1955 S. N.) taken near the southern end of the inclosed area of granite, about halfway between Fennessy and Clover meadows, is a light-gray facies with abundant feldspar phenocrysts, but not much biotite. In thin section (Pl. XI, *B*) this rock appears thoroughly typical. The glass, which makes up the greater part of the slide, is brown and turbid, but shows eutaxitic banding, with excellent flow structure. In this glass lie the phenocrysts of plagioclase, biotite, and augite, with the usual fragments of volcanic rock. The plagioclases are twinned with beautiful sharpness, and several readings on albite-Carlsbad twins indicated a labradorite a trifle more basic than Ab_3An_4. The biotite is rather more abundant than the hand specimen indicates, and occurs in the usual tablets with inclusions of apatite. The augite occurs sometimes in isolated fragments, or anhedra, and sometimes intergrown

Digitized by Google

and partly surrounded by the labradorite crystals. One sharply idiomorphic section of the green hornblende occurs in the slide, being cut transverse to the prism and showing the usual amphibole outline and cleavage. Magnetite is in crystals and aggregates up to 0.5^{mm} in diameter, and, like the augite and biotite, frequently includes apatite crystals.

At a point 3¾ miles southwest of Clover Meadow, and a little over 1 mile west of the bold spur marked *7100* (feet) on the map, occurs a dark-gray facies (1420 S. N.), with the usual phenocrysts of microtine and biotite. It contains small rock fragments, but has on the whole the appearance and consistency of a lava rather than a tuff. The microscope shows the usual structure of these rocks, with the characteristic brecciated eutaxitic glass. The latter is brown and more turbid than is generally the case, and is probably somewhat weathered. Phenocrysts of feldspar are fairly abundant. They are sometimes broken and angular and occasionally slightly embayed, but they often preserve their original crystallographic outlines. Combination twins, according to both albite and Carlsbad laws, are common, and the plagioclase is labradorite. The phenocrysts are generally rather free from inclusions, and show the basal and brachypinacoidal cleavages unusually well. The other phenocrystic minerals are biotite, augite, and magnetite. Apatite occurs in small prisms included in all the other minerals.

Some of the bands and shred-like patches of brown glass show a striking mottled appearance, produced by thickly crowded round spots of shadowy outline, surrounded by darker-brown rims. The lighter central portions of these spots show an obscure radial arrangement, as if from a very imperfect spherulitic structure. No distinct microlites can be made out, however, although there is some slight double refraction between crossed nicols. The usual inclusions of latitic (?) groundmass with lath-shaped plagioclases occur in this facies, but the character of the surrounding matrix, with its fluxion phenomena, precludes the idea of the rock being a tuff. An analysis of this facies is given on page 58, Column VI of the table.

A mile southwest of the little pond in Clover Meadow is a remnant of the biotite-augite-latite (exaggerated on the map), resting upon the andesite breccia. It is very similar in appearance to the facies just described, but shows marked flow structure, which is brought out by atmospheric etching on exposed surfaces. Long-drawn-out and parallel lenses of nearly black glass are noticeable in the hand specimen (1948 S. N.). Under the microscope it is noteworthy for its fine large phenocrysts of labradorite (Ab_3An_4) and biotite and the wavy and contorted areas of clear, light-brown glass. Augite is also present among the phenocrysts, and, what is not known elsewhere in this rock, a few crystals of orthorhombic pyroxene and some scattered grains of olivine. The orthorhombic pyroxene occurs in stout prisms, rounded at the

Digitized by Google

ends, and up to 0.5 mm in length. It is distinctly pleochroic, with strictly parallel extinction and low double refraction, and is readily distinguished from the pale-green, nonpleochroic augite. It is probably enstatite or bronzite, and it appears to be identical in pleochroism and double refraction with the orthorhombic pyroxene in the so-called enstatite-porphyrite of the Cheviot Hills. The olivine is in small irregular grains, and not abundant; but its presence is interesting, as it is rare to find biotite, orthorhombic pyroxene, and olivine all present in an effusive rock of intermediate composition. The green hornblende, frequently referred to as a characteristic accessory in the rock of this flow, occurs both in the glassy part of the section and in one of the included volcanic fragments. There are also present the usual prisms of apatite and a little magnetite.

The large labradorites are often intergrown with the augite, showing that the latter mineral is the younger. All the phenocrysts occur both in the clear brown glass and in the turbid, confused, and microlitic matrix between the clearer streaks. The apatite is included in the glass and in all the larger phenocrysts save the olivine. The more or less rounded fragments of volcanic rock in the section are plainly locally inclusions, but they show a mineralogical resemblance to the rock in which they are inclosed and may not have been derived from a wholly foreign source. Some of them show only very small feldspar microlites embedded in a brown glass like that so abundant in the inclosing rock. One compound inclusion was noted which consisted of several small rounded fragments of microlitic brown glass inclosed in a similar fine groundmass of slightly different color. This strongly suggests that the greater part of the inclusions in the biotite-augite-latite are not foreign material, but represent portions of the magma, which, having attained a certain degree of crystallization, were brecciated by the movement of the lava stream and disseminated through its more glassy portions.

A specimen (1435 S. N.) from the ridge just south of Clover Meadow is a light-gray rock with phenocrysts of biotite and microtine and small rounded fragments of volcanic rock, lying in a fine light-gray and somewhat porous groundmass. This is probably the most tuffaceous facies in external appearance of the whole flow. Under the microscope it shows the usual phenocrysts of labradorite, biotite, and augite in a matrix made up of light-brown glass. The proportion of glass in the slide is larger than usual and has a fine shred-like character. It would perhaps be impossible to determine satisfactorily from a microscopic examination of this slide whether it should be classed as a tuff or not. Some of the shreds of glass, however, are molded to the form of the phenocrysts. A small fragment of green hornblende was observed isolated in the glass, while another crystal, partially resorbed and surrounded by a dark granulated border of augite and magnetite, was seen in one of the fragmental inclusions.

Digitized by Google

An inclusion (1436 S. N.) of much larger size than any observed by me was found by Mr. H. W. Turner in the biotite-augite-latite just described. It measures about 6^{cm} in diameter and is rather angular in outline. It is a hard, compact rock, light gray in color, showing small phenocrysts of plagioclase and augite, and is apparently an andesite. Under the microscope it shows phenocrysts of plagioclase, augite, and orthorhombic pyroxene, with moderate-sized grains of magnetite, lying in a very fine hyalopilitic groundmass. The plagioclases are labradorite, apparently a little more basic than $Ab_3\,An_4$. The albite twinning is not so regular as in the latites, and the combination with the Carlsbad law not quite so frequent, but with the pericline law more so. They frequently show zonal structure with undulatory extinctions, especially in brachypinacoidal sections. The phenocrysts are usually small, few in the section being over 1^{mm} in length.

The orthorhombic pyroxene occurs in nearly colorless crystals of prismatic habit up to about 0.75^{mm} in length, usually with more or less rounded or irregular ends. Cross sections of the prism show rectangular outlines with slightly truncated corners, due to the dominant development of the brachypinacoid and macropinacoid. The prismatic cleavage is well developed, while the macropinacoidal cleavage is indicated only by a few fine cracks. The extinctions are always parallel to the traces of the pinacoids. Sections transverse to the prism show the emergence of a bisectrix, with a large axial angle. By comparison with the interference figures given by longitudinal sections, and by using the method given by Michel Lévy,[1] it was determined that this is the acute bisectrix. The optical orientation is: $a = \mathfrak{a}$, $b = \mathfrak{b}$, and $c = \mathfrak{c}$. The mineral is therefore optically positive. The index of refraction is not noticeably different from that of the monoclinic pyroxene in the slide, but the double refraction is much lower, ranging from gray to pale straw-yellow. The pleochroism is distinct: $\mathfrak{a}$ = very pale brown $\mathfrak{b}$ = very light yellow, and $\mathfrak{c}$ = pale green.

From the foregoing description it is seen that the pyroxene has the optical orientation of enstatite or bronzite; but the distinct pleochroism and large axial angle point rather to bronzite than to enstatite.

This inclusion is accordingly a bronzite-augite-andesite, identical with specimens that will be described from the underlying andesitic breccia, and was probably caught up (with other similar ones noted at the same locality) by the latite from the clastic beds over which it flowed.

The general microstructure of the biotite-augite-latite appears to approach very closely to the *eutaxitic* structure as the term was first employed by Fritsch and Reiss,[2] who applied it to certain facies of phonolites, andesites, and trachytes possessing some resemblances to

[1] Les minéraux des roches, Paris, 1888, p. 95.

[2] Geologische Beschreibung der Insel Tenerife, Winterthur, 1868, pp. 414–422; also abstract in Neues Jahrbuch für Min., etc., 1868, pp. 752, 849–852.

Digitized by Google

clastic rocks and inclosing undoubted clastic fragments. They distinguished *agglomerate lava*, in which the structure was supposed to be due to a partial refusion of clastic material, from *piperno*, in which portions of the magma in different stages of crystallization are brought into juxtaposition by the motion of the flow. Common usage, however, has somewhat altered the original application of the term *eutaxitic*, so that it frequently implies merely a fluidal banding brought about by alternating streaks of microfelsitic and clear glass,[1] or is even used as "a general name for banded volcanic rocks."[2] That such can hardly have been the earlier application of the word appears from the discussion that has centered about the original *piperno* of Pianura in the Phlegræan Fields, near Naples, a rock that Fritsch and Reiss took as the second type of eutaxitic structure, and which appears to resemble in some ways the biotite-augite-latite of California. Luigi dell' Erba[3] considers this rock a tuff, but the greater number of petrographers have regarded it as a lava flow. Zirkel[4] refers to it as a sanidine trachyte with eutaxitic structure, remarking that Luigi dell' Erba's view is not even probable, while Rosenbusch[5] cites it as an example of his Ponza type of the trachyte family. Such a discussion could scarcely have arisen were the structure concerned a simple banding such as is observed in many vitrophyres, and which no petrographer could for a moment regard as indicating a tuffaceous origin. Küch,[6] following the terminology of Reiss, describes both kinds of eutaxitic structure, the agglomerate lava and the piperno, as occurring in the dacites and andesites of Colombia. The latter form is particularly abundant, and Küch remarks that it is at times impossible to distinguish the two varieties, as the piperno often contains included fragments of other andesites. Wichmann,[7] in describing an augite-mica-andesite from the Indian Archipelago having a structure apparently nearly identical with that of the biotite-augite-latite of the preceding pages, refers to it as having piperno structure; and there seems to be little doubt that this latter name, as used by the petrographers cited, expresses accurately the structure of the second flow of the Sierra Nevada latites.

When, on the other hand, a thin section of the last-named rock is compared with that of a lava having typical flow banding—as, for example, the beautiful vitrophyre of San Lugano, in the Tyrol, or the pitchstone-vitrophyre occurring between Lake Lugano and Lago Maggiore, both of which, according to Rosenbusch,[8] often show eutaxitic

[1] Zirkel, Petrographie, 3d ed., Vol. I, 1893, p. 465.
[2] Kemp, Handbook of Rocks, New York, 1896, p. 136.
[3] Giornal di Mineralogía, etc., Vol. III, 1892, pp. 23-54.
[4] Loc. cit., Vol. II, p. 796.
[5] Mikroskopische Physiographie, 3d ed., Vol. II, 1896, p. 766.
[6] Geologische Studien in der Republik Colombia, I Petrographie, 1. Die vulkanischen Gesteine, Berlin, 1892, pp. 84-86.
[7] Petrographische Studien über den indischen Archipel, abstract in Neues Jahrbuch für Min., etc., 1897, Vol. I, p. 283.
[8] Loc. cit., p. 698.

Digitized by Google

facies—the chief difference seems to lie in a greater irregularity and brecciation of the bands in the latite, and in the presence of included rock fragments.

In looking over the large collection of volcanic rocks brought from Asia Minor by the Assos Expedition, and now at Harvard University, it was found that the peculiar structure of the biotite-augite-latite was exactly reproduced in a specimen (A. E. 310) from near the Hot Springs of Touzla, in the southwestern part of the Troad. This specimen, as Mr. J. S. Diller very kindly informed the writer, "belongs to the lower portion of a flow of rhyolite, near its contact with the underlying tuff. The rhyolite some distance away from the contact is deep flesh-red. Near the contact it is frequently black and glassy, inclosing many fragments of the tuff over which it flowed." The hand specimen shows a light-gray, very glassy rock, with streaks of dark glass and abundant angular glassy inclusions of light-buff color, together with small, slightly rounded volcanic fragments, resembling superficially those in the latite.

Under the microscope the similarity of structure is remarkable. The light-brown glassy streaks, alternating with microlitic patches, show the same confused and brecciated appearance as in the latite. Phenocrysts of biotite and feldspar are abundant, and there are numerous small rounded inclusions of some andesitic rock. The structural resemblance between the Touzla rock and the biotite-augite-latite is so close that only a critical investigation of the phenocrysts and inclusions would serve to distinguish an unlabeled thin section of the former from one of the latter. To make the resemblance still closer, no sanidine was seen in the Asia Minor rock, all the phenocrysts in the thin section being plagioclase (andesine or labradorite).

Another specimen (A. E. 531) which, according to Mr. Diller, is from "one of the large flows of rhyolite forming the plateau that lies between the Touzla River and the southern coast of the Troad, west of Assos," shows a very similar structure, while specimens from near Baba-galessi (A. E. 559 and A. E. 560) exhibit gradations into nearly or quite typical unbrecciated flow-banding.

The object of this comparison is not to show that these specimens from the Troad are chemically or mineralogically identical with the biotite-augite-latite, but merely to draw attention to their *structural* identity, and the fact that they occur as true flows and not as tuffs.

As an historical illustration of the difficulty that sometimes exists in distinguishing a tuff from a massive lava may be recited the case of the so-called "peperino" near Viterbo, in Italy, which, according to Washington,[1] is probably a tuff, although it possesses some apparent flow structures, and has been by earlier investigators frequently designated a massive rock.

There has been mentioned the occurrence near Mill Creek of a vitro-

[1] Italian petrological sketches, II: Jour. Geol., Vol. IV, 1896, pp. 838–840.

Digitized by Google

phyric lava which, though underlying some augite-latite belonging apparently to the Table Mountain flow, yet resembles the biotite-augite-latite that usually rests *upon* the latter flow. Megascopically this rock (1866 S. N.) is a gray, extremely brittle glass with a pitchstone-like luster. It is speckled with a few minute feldspar phenocrysts and shows streaks of black glass and also lighter-colored glassy patches resembling inclusions.

Under the microscope the thin section, consisting chiefly of pale violet-brown glass, shows the eutaxitic structure already fully described, but, as might be expected from the megascopic appearance of the rock, approaches a little more nearly the ordinary flow structure of the vitrophyres. This glass contains numerous angular (rarely rounded) fragments of labradorite (Ab_3An_4), less abundant anhedra of pale-green augite, a few flakes of biotite, and an occasional prism of orthorhombic pyroxene. Most of the slides examined also show one or two shreds of green hornblende. Apatite occurs in small prisms, especially as inclusions in the augite, and there are also a few grains of magnetite present. Like the typical biotite-augite-latite, this facies frequently shows small rounded inclusions of volcanic rock consisting of small microlites of plagioclase in a glassy base, but it differs from all the known occurrences of the former in being more glassy and in the paucity of biotite. A chemical analysis of this rock will be found in Column VII of the table of analyses on page 58; it will be seen to have more silica, and less lime, magnesia, iron oxides, and alumina, than the other latites.

Immediately above the facies just described, and also at Clover Meadow, is a rather peculiar lava (1867 S. N. and 1428 S. N.) of light brick-red color, containing a few small empty cavities, but of generally compact texture and speckled with small phenocrysts or fragments of glassy feldspar. In its general aspect the rock is rhyolitic, although differing from the ordinary white rhyolites of the district, which, as far as known, are all older than any of the andesitic breccias. Under the microscope the rock shows phenocrysts of feldspar, frequently broken and angular, with occasional flakes of biotite, lying in a reddish, turbid, microfelsitic groundmass. The feldspars are all plagioclase, and some of the sharply twinned individuals give extinction angles indicating labradorite as basic as Ab_3An_4. The matrix in which they lie has its original structure obscured by secondary silicification and by the separation of ferric oxide, but appears to show some remnants of the vitrophyric structure observed in the preceding rock. There are apparently the same patches of bent and contorted glass, with occasional small rounded inclusions of volcanic rock. A partial chemical analysis of this red lava is given in Column IX of the table of chemical analyses, page 58. It is higher in silica than any of the latites, but too low for a typical rhyolite. The amount and relative proportions of the alkalies, too, give no very definite information as to its proper posi-

Digitized by Google

tion, and it is uncertain whether it should be classed as a somewhat weathered superficial portion of the vitrophyric latite below it, or whether it is a very thin flow belonging rather with the rhyolites. The former supposition, however, seems much more probable, as in the latter case it would indicate a rhyolitic eruption of much later date than that of the normal white rhyolites and rhyolite tuffs which lie at the base of the whole Neocene volcanic series. For this, however, there is no evidence other than the two widely separated and insignificant patches of red lava just described, which is certainly not a typical rhyolite, and does resemble the rather acid latite (1866 S. N.) just beneath it.

THE DARDANELLE FLOW.

The rock of the youngest of the three flows resembles very closely that of the oldest or Table Mountain flow, and this resemblance is in a few cases so close that it would be impossible to say to which flow a given hand specimen belonged. Considered in their typical development, however, the two facies are fairly distinct. The augite-latite (1260 S. N.), forming the extreme summits of the West Dardanelle, may be taken as a typical facies of the Dardanelle flow. This is a dense, nearly black rock, ringing clearly under the hammer and breaking with a clean, slightly conchoidal fracture. The broken surfaces show clear glassy phenocrysts of plagioclase, resembling those of the Table Mountain flow, but smaller, sharper, and less abundant. Their basal cleavage faces show albite lamellæ, frequently combined to form Carlsbad twins. Close inspection will generally reveal a few small phenocrysts of augite, but the plagioclases are the only conspicuous megascopic crystals. They lie in a very compact, nearly black groundmass, in which a good lens can detect only a few feldspar microlites.

The microscope shows phenocrysts of labradorite, augite, and olivine, with apatite and magnetite, lying in a light-brown hyalopilitic groundmass. The labradorites are the largest and by far the most abundant phenocrysts in the slide, but are rarely more than 5^{mm} in length. They are fresh and sharply twinned, but often carry inclusions of glassy base, much as do the larger phenocrysts of the Table Mountain flow, and occasionally include small augites. They are usually tabular parallel with the brachypinacoid, and the prevailing section is lath-shaped. Observations on albite-Carlsbad twins by Michel Lévy's method gave extinction angles indicating a labradorite of the composition Ab_1An_1. The outlines of the phenocrysts are generally sharper and less embayed than in the Table Mountain flow.

The augite is identical with that in the latter flow, but is in smaller crystals and shows a greater tendency toward sharpness of crystallographic outline, especially in the prism zone.

The olivine occurs usually in idiomorphic crystals of small size scattered through the groundmass, but occasionally one of larger size is met with

Digitized by Google

The hyalopilitic groundmass shows sharp, clear feldspar microlites, with more or less flow structure, lying in a light-brown glass. These plagioclases usually show albite twinning with extinction angles corresponding to labradorite. Bifurcated ends are common. The brown semiopaque glass is quite abundant, and makes up a considerable part of the section. It shows a rather noticeable fine mottling, suggesting an incipient spherulitic structure and apparently produced by the crowding together of very minute brown globulites. The magnetite, instead of being minutely disseminated through the glass, as is common in these rocks, forms small crystals and aggregates readily seen with low power.

The specimen just described was taken from the highest point of the peak. A second (1024 S. N.) from near the bottom of the same flow was very similar in thin section, but is slightly weathered. The glass is gray instead of brown, is finely globulitic, and has the magnetite a little more finely disseminated. Apatite, in small prisms, occurs in both slides.

A hand specimen (1421 S. N.) from the summit of the ridge, one-half mile east of Clover Meadow, is megascopically identical with that just described. Under the microscope the chief differences to be observed are a more pronounced flow structure and a slightly greater abundance of augite, olivine, and apatite. The labradorite phenocrysts are more basic, readings on albite-Carlsbad twins indicating a composition near Ab_3An_4. The widths of the albite lamellæ are very variable. The augite phenocrysts occur in stout prisms, very pale green in color, generally crystallographically bounded in the prism zone, but rounded on the ends. Extinction angles were obtained, of $c:\mathfrak{c} = 45°$. The largest augite phenocryst in the slide is less than 2 mm in length. The olivine is in small, sharply idiomorphic crystals, and in larger anhedra from 0.5 mm to 1 mm in diameter. Apatite is noticeably abundant in rather stout, well-formed prisms, both in the augite and in the groundmass. This is evidently a somewhat more basic facies than that on the summit of the West Dardanelle.

The most interesting facies (1419 S. N.) of the Dardanelle flow occurs 3¾ miles southwest of Clover Meadow, at the point where the latites pass under a portion of the andesitic breccias to the west. Megascopically the rock resembles very closely the rocks just described, but the groundmass is apparently slightly more crystalline.

Under the microscope it shows the usual phenocrysts, lying in a groundmass that is distinctly more crystalline than the preceding, and recalls certain facies of the Table Mountain flow. The plagioclases are beautifully twinned according to the albite, together with the Carlsbad, and occasionally the pericline, laws. The extinction angles (30° and 13.5°, 29° and 15°) on albite-Carlsbad twins, cut in a zone perpendicular to the twinning plane, indicate a labradorite somewhat more basic than Ab_3An_4. Some of the larger crystals have glassy inclusions, as in the Table Mountain flow. The specific gravity of these labradorite

Digitized by Google

phenocrysts, determined by suspending a small fragment in Thoulet solution, is 2.667, which is rather low for a labradorite of such basicity as the extinction angles indicate.

The augite is identical with that already described. Sharply idiomorphic cross sections of the prism zone are frequent, and often show twinning on the orthopinacoid. Extinction angles were measured up to $c : \mathfrak{c} = 44°$. Olivine is present only in very subordinate amount.

The groundmass consists of well-developed lath-shaped microlites of plagioclase and small crystals of augite, olivine, and magnetite, lying in a gray cloudy glass. The great preponderance of the feldspars, both in the groundmass and among the phenocrysts, is a striking characteristic of the slide. The lath-shaped feldspars, which are thickly crowded together, are generally twinned, and have extinction angles corresponding to labradorite. When the section is examined with low power and crossed nicols it is very difficult to make out any glass. The spaces between the distinctly lath-shaped plagioclases nearly all show more or less double refraction, the only parts remaining dark being such as are already rendered nearly opaque by thickly crowded globulites. By using an immersion objective, and focusing up and down in the section, it appears that the labradorites of the groundmass are really tabular parallel with the brachypinacoid, and that these faintly doubly refracting portions of the slide are the result of an overlapping of glass and approximately brachypinacoidal sections of labradorite. They generally show the emergence of an acute bisectrix or optic axis in convergent light, which, combined with the fact that they seldom occupy the full thickness of the thin section, is sufficient to account for their low double refraction and rather uncertain extinctions. Naturally they do not show the albite twinning. It was at first supposed that they might be orthoclase, or at any rate a different feldspar from the well-defined labradorite laths, but careful focusing showed that all gradations could be traced from sections of labradorite cut at right angles to the plane of greatest extension, and therefore showing sharp albite twinning and usually occupying the full thickness of the slide, to those cut at an oblique angle and showing more shadowy lamellæ and less distinct lath-shaped outline, and finally to sections cut at only a very small angle with the brachypinacoid, occupying but a fraction of the whole thickness of the section, or thinning out to a feather-edge, and consequently showing no twin lamination and low double refraction.

The glass in which these well-developed plagioclases lie is in itself clear and colorless, but is usually crowded with dark globulites which render it nearly opaque with low or moderate powers. By using Becke's method the clear glass shows a lower index of refraction than the balsam, although the observation is difficult to make on account of the abundant globulites. With a No. VII Seibert immersion lens these globulites, which appear like black, opaque dust particles with low

Digitized by Google

powers, are in part transparent, and composed of a pale greenish substance of high refractive index. Within this substance is frequently a smaller black dot which remains opaque and is probably magnetite. In their general appearance the globulites with dark central spots recall the well-known cells seen in micro-preparations of hyaline cartilage. Not all the globulites, however, are compound. Some are wholly transparent, while others are wholly opaque. It is thought that the transparent greenish substance is probably augite.

A portion of this rock was finely powdered and passed through a No. 120 sieve. The fine dust was sifted out through a piece of linen and the remaining powder washed, dried, and placed in Thoulet solution of about 3.15 sp. gr. A powder at once fell which consisted of augite, olivine, and magnetite. Upon dilution to sp. gr. 2.626, about half the remaining powder came down. This portion was easily separated by a small horseshoe magnet into two parts, a magnetic black powder and a nonmagnetic white powder. The magnetic portion examined under the microscope was found to consist of fragments of the globulitic glass, in which were included microlites of the various minerals of the groundmass, particularly labradorite. The nonmagnetic portion consisted of fragments of labradorite free from glass.

Upon dilution of the heavy solution to sp. gr. 2.485, practically all the powder fell. This portion also was nearly all magnetic, and the magnet left only a small residue of white, nearly pure plagioclase powder. The black magnetic portion seen under the microscope resembled that just described. No great difference could be observed between the powder which fell at 2.626 and that which came down at 2.485, except that the nonmagnetic portion was smaller in the latter. This lack of distinctive difference was probably due to the unusual fineness of the powder and its tendency to float in the fluid. It is evident from the experiment, however, that the globulites consist in part of magnetite, and that the latter mineral forms an important, although not conspicuous, constituent of the rock. The specific gravity of the rock as determined by the chemical balance is 2.61. The glass in which the globulites lie must, accordingly, be light.

In an attempt to determine the part played by the considerable percentage of potash shown in the chemical analysis of the rock (Column IV, page 58), a few grains of the magnetic and of the nonmagnetic powder were treated with hydrofluosilicic acid. The magnetic powder afforded abundant crystals of potassium fluosilicate, as well as of sodium and other bases, while the nonmagnetic grains showed only the fluosilicates of sodium, calcium, and aluminium, indicating that the greater part of the potash is in the undifferentiated glass, a result that accords with its low specific gravity.

The other constituents of the groundmass consist of not very abundant grains and crystals of augite, olivine, and magnetite, some small patches of greenish-yellow serpentine, and an occasional small zircon.

Digitized by Google

A rock remarkably similar to the one just described was found in the Assos collection already referred to. This (A. E. 240) is a dark, compact rock with splintery fracture, resembling a basalt, and labeled as coming from Husseinfagy, Asia Minor. Under the microscope it shows phenocrysts of labradorite and pale-greenish augite. The groundmass shows the same structure as the preceding rock, the same well-developed plagioclase laths, and a glassy matrix thickly crowded with the same dark globulites. The thin section also contains numerous small serpentinous pseudomorphs, after a mineral that was apparently olivine.

In the absence of a chemical analysis it would be hardly safe to assert the practical identity of this rock with the Dardanelle latite; but the work of Washington[1] on the rocks of Smyrna and Pergamon shows that the chemical type of the latites is well represented in this region.

A specimen (1956 S. N.) from the other side of the andesitic ridge, about a mile from the preceding, stands megascopically halfway between the typical Dardanelle facies and the typical Table Mountain facies, showing phenocrysts of labradorite up to 10 mm in length.

Under the microscope the thin section shows the usual labradorite and augite crystals, with smaller ones of magnetite. The olivine is very inconspicuous and appears to be confined to scattered grains or small crystals in the groundmass. The latter, which is rather coarsely hyalopilitic, consists of well-developed laths of plagioclase lying in a light-brown glass. These laths, instead of having squarely truncated ends, show a great tendency toward skeletal forms, splitting up, and projecting long, delicate spines into the glass. Others consist of a thin rectangular shell filled with brown glass. This glass, which occupies a considerable proportion of the slide between the larger laths, has a beautiful frosted appearance, due to its being crowded with still more delicate forms of growth than those of the larger laths. All the latter are well twinned and show extinction angles corresponding to labradorite. Small prisms of apatite and grains of magnetite, augite, and olivine are the other constituents of the groundmass. The glass, when examined with an immersion lens, is seen to be full of minute globulites, which give it its brown color. Some of the larger of these are transparent.

Three-fourths of a mile northward from the locality of the foregoing specimen a remnant of the Dardanelle flow, too small to map without exaggeration, rests upon a larger and broader mass of the biotite-augite-latite. It is very frothy in places, especially near its base, and the specimen (1953 S. N.) taken from the more compact portion shows numerous small round vesicles. Megascopically it resembles closely some of the Table Mountain latite, the labradorite phenocrysts being a little larger and more abundant than in the typical Dardanelle facies. The microscope shows large phenocrysts of plagioclase and smaller ones of olivine and augite lying in a hyalopilitic groundmass.

[1] Am. Jour. Sci., 4th series, Vol. III, 1897, pp. 41-50.

Digitized by Google

The plagioclases are twinned with beautiful sharpness, frequently combining both albite and Carlsbad laws. Determinations made on such compound twins by the method of Michel Lévy, using the convenient little apparatus devised by Jaggar[1] to tilt the section into the proper positions, indicated a mixture somewhat more basic than Ab_3An_4. These phenocrysts are notable for their frequently very irregular outlines and deep embayments. The bays often exhibit the flow structure of the groundmass more conspicuously than other portions, streams of parallel plagioclase microlites curving in and out of their open mouths, and contrasting with the finer stagnant groundmass caught in the deeper ramifications of the bays, and therefore out of reach of magmatic currents.

Next to labradorite, olivine is the most conspicuous phenocryst—an unusual thing in these latites. It forms well-bounded crystals, in the usual stout prismatic forms, sometimes nearly 0.5^{mm} in length. These phenocrysts are not very abundant, as only five were seen in an ordinary thin section about 1.5^{cm} square. The augite is still less abundant, and in smaller phenocrysts than the olivine.

The groundmass is made up of laths of labradorite, small augites and olivines, grains of magnetite, a few prisms of apatite, and brown glass. The labradorite microlites show a tendency toward skeletal forms resembling those described in the preceding slide.

The last specimen (1886 S. N.) of the Dardanelle flow to be described is from the area one-half mile northeast of McKay's, the most westerly point at which the lava belonging to this flow has been identified. It is here slightly vesicular, with the plagioclase phenocrysts arranged with their longer dimensions distinctly parallel. These are sometimes 10^{mm} in length, and show albite and Carlsbad twinning. Their size and number cause the rock to resemble the typical facies of the Table Mountain flow very closely.

Under the microscope it shows large labradorite phenocrysts with the usual abundant inclusions, lying in a groundmass that is something between hyalopilitic and intersertal. It consists of lath-shaped labradorite microlites, crystals of augite, olivine, and magnetite, and an occasional apatite, lying in a brown glass like that in the section just described. A little serpentine is also present in the groundmass, in part replacing grains of olivine and in part in irregular patches. No phenocrysts of augite or olivine were seen.

Fragments of labradorite, picked out from the powdered rock under the microscope, were found by means of Thoulet solution to have a specific gravity of 2.648, which again is low for a normal plagioclase of the basicity indicated by optical tests. But it is extremely difficult to get fragments that are free from glassy inclusions and at the same time large enough to give the best results when suspended in a heavy fluid.

[1] A simple instrument for inclining a preparation in the microscope: Am. Jour. Sci., 4th series, Vol. III, 1897, pp. 129–131.

Digitized by Google

From the foregoing descriptions it can be seen that the typical facies of the Dardanelle flow resembles that of the Table Mountain flow very closely indeed, while in certain facies they are practically identical. The general distinguishing features of the Dardanelle flow are quantitative rather than qualitative. Its phenocrysts are smaller, the groundmass is finer; olivine is not quite so abundant, and occurs in smaller crystals.

ASSOCIATED VOLCANIC ROCKS.

Olivine basalt, as already mentioned, has been met with only at the West Dardanelle, where it forms a thick series of flows, beneath the latites, and rests in part upon the granite and in part upon rhyolite tuff. It is a dark, even-grained rock, in which the only megascopic phenocrysts are some dark-brown crystals up to 0.5 ^{cm} in length, showing a distinct cleavage, and outlines suggesting pseudomorphs after olivine. A little fresh olivine can also be detected with the lens. This rock weathers much more readily than the latites above it, and is otherwise quite different megascopically.

Under the microscope (1007 S. N.) it shows a typical basaltic or intersertal structure, the well-developed plagioclase laths, averaging nearly 0.5 ^{mm} in length, lying in every direction, with the triangular interstices filled with a nearly opaque glassy base and abundant yellow pseudomorphs after olivine. The plagioclase is perfectly fresh and sharply twinned. Combinations of the albite and Carlsbad laws are frequent, and give extinction angles indicating a labradorite rather more basic than the mixture $Ab_3\ An_4$, probably about Ab_2An_3. Olivine occurs with the usual characteristic outline, and is the only mineral that rises to the rank of a phenocryst. It is very abundant, but is rarely fresh, being usually more or less altered to a bright orange-yellow pseudomorphous mineral, which has received the name of iddingsite.[1] The alteration proceeds from without inward, and all stages may be observed from olivines which have just begun to be attacked to those which have been wholly transformed into yellow pseudomorphs. Occasionally there appears to be an intermediate stage, the olivine being bordered by an ordinary greenish serpentine, and this in turn surrounded by the iddingsite. This relationship, however, suggests the possibility that the iddingsite may be an early, or even a magmatic,[2] alteration, whereas the serpentine is the ordinary product of atmospheric weathering. A similar relation was noted in the diabase of Point Bonita.[3] The iddingsite preserves perfectly the sharp idiomorphic outlines of the olivine. In its cleavage, finely fibrous structure, pleochroism, and double refraction it agrees with the iddingsite described from the much older diabase of Point Bonita, which was regarded as being

[1] Lawson, Geology of Carmelo Bay: Univ. of Calif., Dept. Geol., Bull., Vol. I, 1893–96, pp. 31–36. See also Ransome, ibid., Vol. I, pp. 90–92; and Smith, Proc. Calif. Acad. Sci., 3d series, Geology, Vol. I, 1897, pp. 38–40.

[2] See Washington, Italian petrological studies, II: Jour. Geol., Vol. IV, 1896, pp. 835–836.

[3] Loc. cit.

Digitized by Google

probably derived from olivine, although the original mineral had all disappeared.

The augite is not abundant, and is rather unevenly distributed in the slide. It occurs in irregular areas between the labradorite laths, with no crystal form of its own, and has the pale-brown tint characteristic of basaltic augites, as opposed to the greenish augites and diopsides of the andesites. Patches of greenish-yellow serpentine are abundant. They are rounded in outline, and appear to fill small vesicles in the glassy base. The latter forms a considerable part of the rock, and is rendered nearly or quite opaque by a fine black dust, probably magnetite. The specific gravity of the rock is 2.78. A chemical analysis will be found in Column VIII of the table on page 58.

Andesitic breccia or tuff of the ordinary Sierra Nevada type is, as already stated, very abundant in this region. It is not, petrographically speaking, a particularly interesting rock, and in spite of its clastic origin the larger fragments show a fairly uniform character over the whole district. They are usually composed of a hornblende-pyroxene-andesite, in which the large brown hornblende phenocrysts are in various stages of resorption in different specimens, so that this mineral is sometimes a conspicuous and abundant porphyritic constituent, occasionally showing crystals up to 2.5^{cm} in length, and at other times has almost wholly disappeared. The other phenocrysts seen in thin section are labradorite, characterized by zonal structure and undulatory extinctions, pale-green augite, orthorhombic pyroxene, and occasionally olivine, all lying in a hyalopilitic groundmass with rather abundant glass. Although many specimens and thin sections have been studied from different parts of the area, three only, collected from the breccia just beneath the latite south of Clover Meadow, will be described in full as fair types of the whole.

The first of these (1437 S. N.) is dark gray in color and shows black phenocrysts of hornblende up to 5^{mm} in length, and a few small plagioclases, lying in a dark, fine-grained matrix. Under the microscope it shows large phenocrysts of brown hornblende with abundant smaller ones of plagioclase, rather less numerous augites, and still less abundant orthorhombic pyroxene. Among the smaller, less conspicuous phenocrysts might also be included olivine and magnetite. The groundmass is light brown in color and hyalopilitic.

The hornblende is the usual brown variety, and the large crystals are rounded in outline and surrounded by the opaque resorption rims common in andesitic rocks. There is frequently also an outer border which is distinguishable from the groundmass in being clearer and in the local abundance of augite and magnetite grains.

The plagioclase phenocrysts give extinctions of albite-Carlsbad twins corresponding to labradorite (Ab_3An_4). They are rather small, but very abundant, and are characterized by zonal structure and undulatory extinctions, particularly in sections approximately parallel to the

Digitized by Google

brachypinacoid. In this respect they are well contrasted with the sharp regular twinning and definite extinctions of the labradorite of the latites.

The augite is pale green to nearly colorless, and gives extinction angles of $c : \mathfrak{c} =$ about 45°. It is frequently idiomorphic in the prism zone, and is in general like the augite of the latites.

The orthorhombic pyroxene occurs generally in smaller and more slender prisms than the augite. It is in every way similar to that described on page 42 in an andesitic inclusion in the biotite-latite, and, as shown by its faint pleochroism and double refraction, is probably bronzite rather than enstatite.

The olivine is in small grains and irregular crystals and is quite accessory in amount.

The groundmass consists of small microlites of plagioclase, usually showing albite twinning, and brown glass. The rock may be called a hornblende-augite-bronzite-andesite.

A second specimen (1438 S. N.) from the same breccia resembles the preceding, but is a little darker in color and shows numerous crystals of dark olive-green augite 2 or 3 mm in length. The microscope shows large phenocrysts of augite and smaller ones of plagioclase and olivine, lying in a microlitic glassy base. The large augites are very pale yellowish-green in color and nonpleochroic. They sometimes show crystallographic outlines, and are sometimes rounded. The angle $c : \mathfrak{c}$ was found to be at least 46°.

Brown hornblende in large rounded phenocrysts with black resorption rims also occurs in the rock, but only a single fragment was included in the thin section studied.

The plagioclases are prevailingly broad lath-shaped in outline, with a central portion full of small glass inclusions. They generally show twinning according to the albite law, not infrequently combined with the Carlsbad law. The measurements of the extinction angles of these two sets of lamellæ indicate a labradorite rather more basic than Ab_3An_4.

Olivine is rather abundant, in more or less idiomorphic crystals of small size, with occasional larger anhedra, and is quite fresh.

The groundmass is rather glassy, but contains grains of magnetite and abundant small microlites. Lath-shaped microlites of feldspar are, however, notably lacking, and the groundmass can scarcely be called hyalopilitic. Apatite is present in small amount as inclusions in the augite. The rock may be called a hornblende-augite-andesite, but the abundance of the olivine indicates a rather close relationship with the basalts.

A third specimen (1439 S. N.), much like the preceding, but less plainly porphyritic, is dark gray in color and somewhat basaltic in appearance. The lens reveals small plagioclases, with augite and olivine, in a fine dark groundmass. Under the microscope it shows the same general structure as the preceding rocks. The augite, however,

Digitized by Google

is in smaller phenocrysts and not quite so abundant, and no hornblende appears in the slide. The olivine, on the other hand, is present in rather greater amount, often partly serpentinized. The plagioclase is labradorite (Ab_3An_4), frequently showing wavy extinctions and zonal structure. The inner portions of the crystals are usually the more basic. The rock would be classed as an augite-andesite.

Types of andesite other than those described may be found among the fragments of the breccia in different portions of the region. On the ridge just north of Beaver Creek a beautiful light-gray hornblende-andesite (1966 S. N.) was collected, in which the pyroxene present is confined to an insignificant amount in the groundmass. The hornblende in this facies is green in transmitted light, with the pleochroism $\mathfrak{a}$ = light greenish yellow, $\mathfrak{b}$ = olive green, and $\mathfrak{c}$ = dark yellowish green. The absorption is $\mathfrak{b} = \mathfrak{c} > \mathfrak{a}$, and $c : \mathfrak{c} = 16°$ at least. Another light-gray fragment (1975 S. N.) with conspicuous porphyritic hornblendes, taken from the breccia 3½ miles northeast of Fennessy's, shows the usual brown hornblende in thin section. The groundmass contains abundant small microlites, which appear to be enstatite. A thoroughly typical hornblende-andesite was collected 3 miles south of Big Trees in which the hornblende phenocrysts are abundant. Seen in thin section, they are surrounded by narrow black rims and show strong pleochroism, $\mathfrak{a}$ = light yellowish green, $\mathfrak{b}$ = bright chestnut-brown, and $\mathfrak{c}$ = deep rich mahogany-brown. The absorption is $\mathfrak{a} < \mathfrak{b} < \mathfrak{c}$. The groundmass is typically hyalopilitic and contains a little augite. Other andesites occur in which the hornblende, if, as seems probable, formerly present, has been wholly resorbed, giving pyroxene-andesites in which augite and orthorhombic pyroxenes vary in relative proportions. The rarer accessory minerals of the intermediate effusive rocks are not well represented in the Sierra Nevada andesites. A small crystal of zircon can occasionally be detected, and a single crystal of rutile (?) was noted in one thin section.

No chemical analyses have been made of the andesites of this area, but they probably do not depart from the ordinary Sierra Nevada type, in which total alkalies are generally less than 6 per cent, with soda in excess of potash. Some analyses of these andesites have recently been published by Turner.[1]

Massive rhyolite occurs within the area of the map only at the point previously mentioned, just west of the Dardanelles. It is a fresh, nearly white rock, showing small phenocrysts of sanidine and a pale-pink feldspar, with a few grains of quartz, lying in a cryptocrystalline groundmass. Under the microscope it shows phenocrysts of sanidine with an occasional acid plagioclase and small biotite scales in a nearly colorless, homogeneous, microfelsitic groundmass. The sanidine does not show good crystal outlines, and is without twinning. It has a lower index of refraction than the balsam, a specific gravity as determined

[1] Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 731.

Digitized by Google

by Thoulet solution of 2.542, and yielded abundant octahedra of potassium fluosilicate with hydrofluosilicic acid. The quartz occurs in little nests of interlocking grains and not as distinct porphyritic crystals. The groundmass shows a few scattered grains of magnetite and a small crystal of zircon.

Rhyolitic tuff is much more abundant than the massive rhyolite within the district studied. It is usually white in color, fine grained, and somewhat friable, although secondary silicification has frequently indurated the exposed surfaces of the beds. The coarser, more crumbling facies generally show fragments of sanidine, microtine, and quartz, and sometimes, as on the south side of the Dardanelles, water-worn pebbles of foreign material. As mentioned in the preceding pages, this tuff sometimes shows columnar structure.

Under the microscope the rhyolite tuff usually shows more or less angular fragments of sanidine, plagioclase, and more rarely quartz, with scales of biotite, lying in a nearly colorless matrix. The latter is almost isotropic, but is generally somewhat chalcedonized. Most of the sections show the "aschen-structur" of Mügge[1] in great perfection, and all intermediate facies occur between those made up of the fresh crescentic glass spicules of a finely comminuted volcanic ash[2] (1823 S. N.) and those in which secondary silicification has in great part replaced the intricate reentrant curves of the glass shards by finely radial, concentric bands of chalcedony, polarizing feebly between crossed nicols, and giving rise to a kind of secondary axiolitic structure common in older rhyolitic tuffs and concerning whose origin there has been some debate (1973 S. N.).

Various tuffs occur within the area embraced by the map which differ somewhat from the ordinary gray andesitic tuffs of the region. They are generally finer, softer, and lighter in color than the latter and are found only in a few small patches. Microscopic investigation shows that they are either andesitic or latitic in character, the distinction between the two being not readily made in their tuffaceous forms.

A mile and a half south of Fennessy's a thin stratum of porous, light-gray tuff (1978 S. N.) rests upon the biotite-augite-latite and separates it from the overlying andesitic breccia. Megascopically this shows abundant small fragments of white pumice inclosed in a finely comminuted volcanic paste. Under the microscope it exhibits numerous areas of nearly colorless pumiceous glass, together with crystals of labradorite, augite, brown and green hornblende, biotite, and apatite. The biotite occurs both as isolated crystals and inclosed in the pumiceous glass. There are also abundant fragments showing microlitic glassy base, some of which appear to be andesite, while others resemble the fine groundmass of some of the massive latites. The apatite is in small prisms, and the slide also contains a little magnetite and epidote. The presence of biotite, which was not found in the andes-

[1] Neues Jahrbuch für Min., etc., Beilage-Band 8, p. 648. See also G. O. Smith, Geology of the Fox Islands, Maine, Skowhegan, 1896, p. 39.

[2] Diller, Science, Vol. IV, 1884, pp. 651–654.

Digitized by Google

ites of the region, and the absence of orthorhombic pyroxene, suggest that this tuff may belong to the latitic series.

Just south of Mill Creek, near its mouth, the augite-latite, capping the small hill previously described, is underlain by three beds of soft tuff. The lowest of these is light-yellow, friable tuff, containing fragments of fine white pumice and small rolled pebbles. Under the microscope it is seen to be made up of glass shards showing typical ash structure, with fragments of pumice and a few grains of clastic quartz, the whole being somewhat chalcedonized.

The bed just above this is a fine, white volcanic sand that was not microscopically examined, while the topmost bed is apparently an ordinary andesitic tuff, albeit somewhat finer than is common in this region.

CHEMICAL COMPOSITION OF THE SIERRA NEVADA LATITES.

In the accompanying table (p. 58) the chemical analyses of the latites form all three flows are brought together for comparison. In spite of a certain range in the silica percentages, they are all closely related members of a series. They are not far from the andesites in general composition, but are slightly higher in silica and distinctly so in alkalies, the potash being always slightly in excess of the soda.[1] Compared with typical trachytes, these rocks are higher in lime and magnesia and lower in silica and alkalies, while the preponderance of potash over soda is usually much more marked in the trachytes.

As would be expected from the microscopical study of the thin sections, the rock of the Table Mountain flow is somewhat more basic than the biotite-augite-latite, while the Dardanelle facies occupies an intermediate position. The Shaws Flat rock (Column I) shows the greatest basicity; the greater amount of lime and magnesia, as compared with the other analyses, being in harmony with the slightly greater abundance of olivine and augite as observed in the thin section. Titanic oxide is present in all the analyses, and usually in noticeable amount, indicating that the magnetite of the rocks is probably titaniferous. Analysis VI is exceptional in containing a small amount of carbon, which is doubtless due to some organic matter included in the lava.

The most noteworthy feature of the analyses, however, taken in connection with the mineralogical composition of the rocks, is the amount of potash shown. As already stated, by far the greater number of the thin sections (excepting, of course, the biotitic facies, which, however,

[1] It is important to note that this statement applies only to the percentage figures in the analyses. When the *molecular* proportions of soda and potash are compared it becomes apparent that, as far as the actual mineral-forming efficiency of these alkalies is concerned, it would be more accurate to say that they are very nearly equal; for the soda molecule may sometimes be present in slightly greater amount than the potash molecule, although the preponderance, when reckoned in percentages, is in the other direction. But as rock analyses are not yet, as a general thing, molecularly expressed and compared, the common mode of percentage comparison has been retained in the characterization of the latites. The petrographer accustomed to translate his chemical analyses into molecular proportions will not, when reading the following pages, lose sight of the suggestion embodied in this note.

Digitized by Google

are no richer in potash than the others) contain no characteristically potash-bearing mineral. Several of the analyses contain as much as 5 per cent of potash, which, if it were present in the form of orthoclase, would make up nearly 30 per cent of the rock. This amount is entirely too large to be accounted for by the assumption that it is present in the form of orthoclase microlites which have escaped detection among the plagioclases of the groundmass. It is fairly certain that nearly all of the potash in those facies which do not contain biotite is present in the residual glass of the groundmass. This conclusion harmonizes with the results of the micro-chemical tests described on page 49, and with the previously noted low specific gravity of the glass.

Frequently[1] in rocks of intermediate composition, like the latites, the orthoclase forms a thin envelope around the basic plagioclases, while in the plutonic monzonites the orthoclase was the last mineral to crystallize, forming a mesostasis for the earlier minerals. In the Sierra Nevada latites the conditions under which orthoclase (or some other potash-alumina silicate) would separate out were never reached. This indicates that the method sometimes employed of assuming the presence of orthoclase in the groundmass of an effusive rock from the character of the bulk analysis is one that requires caution in its use.

Table of chemical analyses of Sierra Nevada latites and associated volcanic rocks.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
SiO_2	56.19 .936	59.88 .998	56.78 .946	59.43 .990	61.09 1.018	62.33 1.039	65.81 1.096	48.76	67.57
TiO_2	.69	.....	1.15	1.38	.....	1.05	.54	1.26	.....
Al_2O_3	16.76 .162	.....	16.86 .163	16.68 .161	.....	17.35 .168	15.11 .146	16.60	.....
Fe_2O_3	3.05 .019	.....	3.56 .022	2.54 .015	.....	2.98 .018	1.85 .011	5.60	.....
FeO	4.18 .058	.....	2.93 .040	3.48 .048	.....	1.63 .022	1.40 .019	5.01	.....
MnO	.10	.....	none	trace	.....	.08	.....	none	.....
MgO	3.79 .094	.....	3.41 .085	1.84 .046	.....	1.05 .026	.37 .009	6.93	.....
CaO	6.53 .116	5.09 .090	6.57 .117	4.09 .073	4.94 .088	3.23 .057	1.98 .035	8.79	.....
BaO	.19	.....	trace	.14	.....	.24	.10	trace	.....
Na_2O	2.53 .040	3.90 .062	3.19 .051	3.72 .059	3.69 .059	4.21 .067	2.59 .041	2.47	5.57
K_2O	4.46 .047	5.06 .053	3.48 .036	5.04 .053	5.27 .055	4.46 .047	5.24 .055	.66	4.33
P_2O_5	.55	.....	.42	.58	.....	.29	.23	.19	.....
H_2O above 110°	.66	.....	1.21	.72	.....	.75	.....	2.19	.....
H_2O below 110°	.34	.....	.15	.27	.....	.44	.....	1.49	.....
	SrO, tr. Li_2O, tr.		CO_2. 18	ZrO_2. 08 SrO, tr.		SrO .05 Li_2O, tr. FeS_2. 08			
				Cl .05		C .11		CO_2. 42	
Total	100.02	.....	99.89	100.04	.....	100.33	.....	100.37	.....
Sp. gr	.....	.....	2.67	2.61	.....	2.49	2.38	2.78	2.23

[1] See Washington, Jour. Geol., Vol. IV, 1896, p. 551, for several references.

Digitized by Google

I. Augite-latite (36 S. N.), Table Mountain flow, Tuolumne Table Mountain, near Shaws Flat. Turner, Rocks of the Sierra Nevada, Fourteenth Ann. Rept. U. S. Geol. Survey, p. 491. Hillebrand, analyst.

II. Augite-latite (86 Tuol.), Table Mountain flow, 3 miles southeasterly from Big Trees. Turner, Geology of the Sierra Nevada, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 727. Fireman, analyst.

III. Augite-latite (1422 S. N.), Table Mountain flow, spheroidal facies, about 1½ miles east of Clover Meadow. Steiger, analyst.

IV. Augite-latite (1419 S. N.), Dardanelle flow, 4 miles southwest of Clover Meadow. Stokes, analyst.

V. Biotite-augite-latite (85 Tuol.), 3 miles southeasterly from Big Trees. Turner, Geology of the Sierra Nevada, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 727. Fireman, analyst.

VI. Biotite-augite-latite (1420 S. N.), 4 miles southwest of Clover Meadow. Turner, loc. cit. Hillebrand, analyst.

VII. Vitrophyric latite (?) (1866 S. N.), just south of Mill Creek. Analysis partial. Steiger, analyst.

VIII. Olivine-basalt (1007 S. N.), west peak of the Dardanelles.

IX. "Red lava" (1867 S. N.), just south of Mill Creek. Ransome, analyst.

CLASSIFICATION OF THE LATITES.

With the great advance in methods of petrographical research during recent years there has come inevitably greater difficulty and complexity in the proper classification of the rocks themselves. The greatly increased accuracy of chemical analyses, particularly as regards amounts of the alkalies and minor constituents, and their more critical interpretation, together with the strides made in the optical investigations of the feldspars by Becke, Federow, Michel Lévy, and others, is leading to the gradual splitting up of some of the older and more comprehensive groups. A notable example of this tendency was Brögger's differentiation of the monzonite family from the syenites, while a similar process has been long reducing the once large family of the trachytes to a size more commensurate with the minor importance of their plutonic equivalents. With the establishment of new families there has come into the literature an enormous number of new names. In many cases these names are local, being based on mineralogical combinations and distinctions that may not be repeated in another region or be given the same value by other observers. The common custom of providing such facies with a name derived from the locality in which they occur is a useful one, but the local, and to a certain extent provisional, nature of such names should be borne in mind, and they should not be allowed to bury under their accumulating mass broader and more rational schemes of classification.

On the other hand, it is no part of pure petrographical science to aim directly at ease and simplicity in classification, however anxiously such an end may be desired by the general geologist. Petrography in its present stage is occupied rightly with critical distinctions. It is only by the recognition of such slight points of difference that they can ever be transcended and assigned their true value in a really rational scheme of rock classification.

Recognizing the fact that igneous rocks are, chemically, mixtures of practically infinite variability within certain limits, the refining tendency of modern methods makes more and more for precision of

Digitized by Google

definition and consequent subdivision of the older groups. This gain in exactness by no means makes easier the classification of a given rock, for it is evident that the greater the number of families the more numerous will be the intermediate or transition rocks, since sharp lines of demarcation apparently nowhere prevail between closely related types. It is a question, of course, how far for purposes of practical description such subdivision of larger groups should go, but it is a question that may very well be answered by the facts of geological occurrence. If a magma of a certain intermediate type with reference to two or more well-established families is found to possess geological unity, and particularly if it is found to be represented by both plutonic and effusive forms, there can be little doubt of the advisability of giving it a distinctive name. Brögger's monzonite magma is an example of such a case, and he has shown very conclusively that the plutonic monzonites, being orthoclase-plagioclase rocks, should be separated from the orthoclase rocks, or granites and syenites, on the one hand and from the plagioclase rocks, or diorites and gabbros, on the other, the mineralogical distinction being the visible sign of difference in chemical composition. In his tabular classification[1] he has indicated the effusive equivalent of monzonite as *trachyt-andesit*, and it is here that the latites of the present paper belong, as will now be more fully shown.

It is plain from the descriptions of the latites in the preceding pages that, in spite of their superficial basaltic character, they are in no sense basalts, being far too high in silica and alkalies and too low in magnesia and lime, and differing from the latter rock in microscopical structure and in the proportion of the ferromagnesian constituents to the feldspars. Their specific gravity, too, is lower than that of basalts of equally compact texture.

Their relation to the andesites is much closer, and were it advisable to crowd them into one of the well-established older groups they would be placed with little hesitation in this family. Leaving out of consideration the glassy base, the particular latites here described possess practically the mineralogical composition of andesites. But they differ from normal andesites in chemical composition, being generally slightly lower in lime and magnesia and always higher in alkalies. In the andesites the total alkalies are as a general rule less than 6 per cent, with soda in excess of potash. In the latites the total alkalies range from 6 to 10 per cent, with the potash equal to or slightly in excess of the soda.

Rocks of this type can hardly be classed as trachytes if the latter name is to retain any precision of meaning. Not only are they decidedly untrachytic in color and texture, but they differ widely mineralogically from typical trachytes. Sanidine, instead of being the dominant feldspar, is entirely absent and the conspicuous feldspar is here

[1] Die Eruptivgesteine des Kristianiagebietes; II. Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol. Kristiania, 1895, p. 60.

Digitized by Google

labradorite. As already noted, Turner[1] has provisionally classed some of the latites with the trachytes on the basis of their chemical composition. The analysis upon which he bases his comparison is quoted from Zirkel's Lehrbuch der Petrographie,[2] and, as Turner remarks, "contains more lime and less silica than most of the analyses given by Zirkel." The analysis in question is one by Ricciardi[3] of the so-called "trachyte" of Bolsena, and is quoted in Column VI of the table of chemical analyses on page 66. Concerning this "trachyte" Washington writes:

> Vom Rath first called attention to the abnormal chemical character of the "trachyte" of Bolsena, though he speaks of it as containing no plagioclase, probably owing to the rarity of the multitude twinning. As will be seen from Klein's descriptions and my own, and from the analyses, the peculiar "trachytes" of the region are remarkable; mineralogically for their richness in plagioclase and the frequent occurrence of olivine as an essential constituent, and chemically for their low silica and high lime and magnesia. Therefore they are not trachytes proper, but correspond to the trachy-dolerites of Abich and Hartung, and to some of the andesitic trachytes of Rosenbusch, and we shall see that they may be regarded as effusive representatives of Brögger's abyssal monzonites. These olivine-free effusive rocks will be called by the name of *Vulsinite*, from the Etruscan tribe Vulsinii, formerly inhabiting this region.[4]

There is thus fresh confirmation of the result already stated, that the latites of the present paper belong neither with the normal trachytes nor yet with the normal andesites, but occupy a position chemically about midway between the two.

Effusive rocks with a chemical composition corresponding to this intermediate taxonomic position appear to be not uncommon, and on page 66 the chemical analyses of a number of such rocks are placed together in tabular form for comparison. Nos. I to XIX inclusive are analyses of latites (which in the table are given the names assigned them by the authors quoted), while No. XX is the mean of the 19 analyses which precede it. Nos. XXI and XXII in the second division of the table are a typical andesite and a typical trachyte respectively, being inserted to show the intermediate character of the latites. The latter as a whole form a fairly uniform chemical series, of which the mean agrees closely with the analysis in Column IX.

But when attention is directed to the names and descriptions of the various effusive rocks embraced in the table they are found to be remarkable more for variety than for uniformity. Thus, besides the latites described in the present paper, there occur such names as *ciminite*, *biotite-vulsinite*, *olivine-bearing andesitic trachyte*, *biotite-dacite*, and *sanidine-bearing andesite*. At first glance such an abundance of names for effusive rocks of a single chemical type seems to indicate little else

[1] Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 729.

[2] Vol. II, 1893, p. 378.

[3] Klein, Petrographische Untersuchung einer Suite von Gesteinen aus der Umgebung des Bolsener Sees: Neues Jahrbuch für Min., etc., B. B. VI, 1889, p. 8.

[4] Italian petrological sketches: Jour. Geol., Vol. IV, 1896, p. 547.

Digitized by Google

than a state of hopeless confusion in rock nomenclature. But while a certain amount of confusion does undoubtedly exist, the multiplicity of names has its chief explanation suggested in two other facts—partly, as pointed out by Iddings,[1] that rock series as they occur in nature may traverse existing schemes of classification at practically any angle, but mainly, in this case, that the name of a rock is generally determined more by its mineralogical than by its chemical composition.

In the case of most igneous rocks, and of nearly all plutonic rocks, the principal mineralogical constituents can be deduced with a fair degree of certainty from an accurate bulk analysis, and, vice versa, from a microscopical examination of a thin section the chemical constitution can be predicted with sufficient accuracy to leave little doubt of the general position of the rock in any ordinary scheme of classification. But with the effusive latites this appears to be true only in a slight degree. In effusive rocks of intermediate chemical composition the circumstances which determine the crystallization of the different possible mineralogical combinations appear to depend upon a very delicate adjustment of physical and chemical conditions. This is already noticeable in the andesites, where a given magma cooling under certain conditions may give rise to a hornblende- or biotite-andesite, and under other conditions, by the magmatic resorption of these two minerals, may solidify as a pyroxene-andesite. The latites, being intermediate rocks par excellence, and containing more or less unindividualized glass in reserve, exhibit this apparent capriciousness of crystallization in an unusual degree.

Thus the vulsinites of Washington "are characterized mineralogically by the presence of alkali feldspar with a large amount of basic plagioclase (labradorite to anorthite), together with augite and diopside. Hornblende and biotite are not abundant in the type specimens, though they may be present in large amounts in other varieties. . . . Olivine is wanting, or if present is so in only accessory amounts."[2] It should be stated that the facies which Washington regards as his most typical vulsinite contains over 9 per cent of potash, and accordingly approaches somewhat nearer to the trachytes than do the typical latites of the Sierra Nevada.

The biotite-vulsinite from Monte Santa Croce (Column II) is particularly interesting with reference to the point under discussion, and the dilemma in which one is placed in attempting to adhere to a purely mineralogical classification of these rocks is well expressed in Washington's own words. He says:

> We have then a rock which is chemically a ciminite and mineralogically a biotite-vulsinite. In regard to the name by which they should be called there may be some doubt. From a mineralogical standpoint they are obviously not ciminite, nor chemically can they strictly be called vulsinite. Since, however, in the schemes of classification in general use at the present time, the mineralogical composition takes

[1] Jour. Geol., Vol. III, 1895, pp. 955–956.
[2] Jour. Geol., Vol. IV, 1896, p. 553.

Digitized by Google

precedence over the chemical, and bearing in mind the unadvisability of adding new names to the already overburdened nomenclature, I shall designate these rocks as biotite-vulsinite.[1]

The ciminites are "characterized mineralogically by the presence of orthoclase, with basic plagioclase, augite or diopside, or olivine."[2]

The andesite from Carbezo Felipe contains phenocrysts of feldspar and biotite. Sanidine occurs in crystals over a centimeter in length, but the main bulk of the feldspar is labradorite, or a plagioclase between labradorite and andesine. Both monoclinic and orthorhombic pyroxenes are present, and the rock is rich in zircon and apatite. Concerning the classificatory position of this rock Osann writes:

> The proportion of the alkalies shows that the rock stands close to the group of andesitic trachytes—a position which is indicated also by the presence of the large sanidine phenocrysts. The content in lime and potash, contrasted with the small amount of soda, is explained by the fact that basic plagioclase (labradorite) occurs as phenocrysts with the sanidine. If the analysis is compared with the analyses of other andesitic trachytes, in part olivine-bearing (Mte. Amiata, the Arso flow, Mte. Alfina), it is seen to be higher in magnesia. (The Arso rock, in spite of the presence of olivine, has only 1.77 per cent.) This is explained only by the abundance of both biotite and orthorhombic pyroxene.[3]

The augite-andesite from Mount Pagos is "composed of plagioclase, diopside, and biotite, with accessory magnetite, apatite, and zircon, lying in a glass base."[4] The plagioclases are labradorite ($Ab_1 An_1$), but there are possibly a few orthoclase microlites in the groundmass.

The Gleichenberg trachyte contains, according to Hussak,[5] large sanidine phenocrysts, fewer and smaller ones of oligoclase (with extinction angles of 12°–15°), biotite, and dark augite, in a globulitic base.

The augite-andesite from Kara Tash has numerous phenocrysts of labradorite (a little more basic than $Ab_1 An_1$), pale-green diopsides, some biotite, and grains of magnetite, in an abundant, trichitic, glassy base.[6]

The biotite-dacite from Pergamon[7] contains phenocrysts of labradorite, with fewer sanidines, biotite, and olive-green hornblende. The rock is called a dacite on the basis of its chemical composition, although containing no free quartz, thus again illustrating the difficulties attendant upon a consistent mineralogical classification of these intermediate rocks.

The sanidine-bearing andesite of the Rosita Hills is described by Cross[8] as containing plagioclase, orthoclase, quartz, biotite, augite, and

---

[1] Jour. Geol., Vol. V, 1897, pp. 250–251.

[2] Ibid., Vol. IV, 1896, p. 838.

[3] Beiträge zur Kenntniss der Eruptivgesteine des Cabo de Gata, II: Zeitschr. Deutsch. geol. Gesell., vol. 43, 1891, p. 720.

[4] Washington, On some igneous rocks from Smyrna and Pergamon: Am. Jour. Sci., 4th series, Vol. III, 1897, p. 44.

[5] Zirkel, Lehrbuch der Petrographie, Vol. II, p. 383.

[6] Washington, loc. cit., p. 44.

[7] Washington, loc. cit., p. 48.

[8] Proc. Colorado Sci. Soc., 1887, p. 248.

Digitized by Google

accessory minerals. This rock is said to have its chief development in dikes, although occurring also in effusive masses.

The foregoing citations are sufficient to show how great mineralogical variety may be presented by rocks having the peculiar intermediate chemical composition of the latites. It is possible, and perhaps desirable, to assign the more conspicuous and well-marked of these mineralogical combinations separate names, but the number of the latter is apt to be large, and they are of a distinctly lower grade of importance than those rock names which express not only a certain mineral constitution but a corresponding and characteristic chemical composition as well.

It accordingly seems advisable to attempt to bring into common use some more general name to embrace all the effusive rocks standing chemically about midway between the typical trachytes and the typical andesites—a name that can be used as the effusive equivalent of the increasingly important plutonic group of the monzonites. I should gladly have avoided the necessity of introducing a new name into a rapidly growing nomenclature; the more so, as Washington, by his admirable petrographical studies in the Italian volcanic regions, has added so greatly to an accurate knowledge of intermediate rock types which must be necessarily embraced by such a new term. But the Sierra Nevada lavas can not be classed with the typical toscanites, vulsinites, or ciminites, as defined by Washington, although, like the vulsinites and some of the ciminites, they are to be regarded as the effusive equivalents of the monzonites. There is thus a demand for some more comprehensive name to cover the mineralogically diverse forms which the monzonitic magmas, cooling under effusive conditions, may assume. For this reason, and in recognition of the importance and interest of the Italian types described by Washington, the name *latite*, derived from the Italian province of Latium, is proposed as a broader term, comparable in its scope with *monzonite*, to designate the effusive forms of the monzonite magma. Thus it will be seen that certain of the characteristic features of the Sierra Nevada latites, such as the absence of sanidine, the predominance of labradorite, and the presence of a residual alkali-rich glass base, are not regarded as essential in the definition of the general group of the latites as a whole. The latites described in the present paper are merely members of this group, possessing individual characters which would entitle them to names of the same order of importance as the vulsinites, toscanites, etc., of Washington. For the present, however, no such names are proposed.

Abich and Hartung have used *trachy-dolerite* for rocks which in part belong with the latites; Fouqué and Michel Lévy, *trachy-andesites;* Zirkel and Rosenbusch, *andesitic trachyte;* and Brögger *trachyte-andesite.* But all these compounds are open to objection when a name is required for an important group standing midway between the trachytes and the andesites. Such a name should consist of a single word, and

Digitized by Google

should be free from the undesirable connotations adherent to compounds which have been variously employed.

Referring again to the table of chemical analyses on page 67, it will be seen that in Columns XXIII and XXIV are placed the analyses of two quartz-banakites, chosen as being the nearest known dike equivalents of the latites[1]. The correspondence, however, is not quite perfect, as the two analyses show a slight deficiency in lime and a small excess of alkalies as compared with the mean of the latite analyses. Iddings[2] states that the rocks of these two analyses belong to the banakite series "both mineralogically and chemically, but are somewhat more siliceous, having 5 to 9 per cent more silica. They might properly be given specific names, but at present we prefer to class them with banakite, under the name of quartz-banakite, the amount of quartz, however, being very small."

The banakites are intermediate rocks in the same sense that the latites are. Chemically they possess a rather close analogy with the latter rocks, although somewhat lower in silica, and thus tending through leucitic facies toward the truly alkaline groups of igneous rocks. It is interesting to note that Iddings[3] remarks in this series the tendency toward mineralogical diversity with nearly identical chemical composition, already emphasized in the case of the latites.

In the succeeding columns of the table are placed the analyses of several monzonites, quoted from Brögger, in order to show the close relationship between these plutonic rocks and the effusive latites. Washington has already pointed out this correspondence in the case of his vulsinites and ciminites,[4] and notes as well analogies with the absarokite-banakite series of Iddings.[5]

---

[1] After the foregoing was in type my attention was drawn to the dike rock described by Hibsch as occurring in the Bohemian Mittelgebirge, which he has named *gautsite*. (Erlauterung zur geologischen Karte des böhmischen Mittelgebirges: Tschermaks min. u. pet. Mitth., vol. 17, 1897, pp. 84–87.) This rock also is perhaps a dike equivalent of the monzonites and latites, although the chemical analysis shows rather high alkalies.

[2] Absarokite-shoshonite-banakite series: Jour. Geol., Vol. III, 1895, pp. 949–950.

[3] Loc. cit., p. 951.

[4] Jour. Geol., Vol. IV, 1896, p. 832.

[5] Ibid., loc. cit., p. 838. Since the foregoing was written Washington's final paper on the Italian volcanic regions has appeared (loc. cit., Vol. V, 1897, pp. 349–377), in which he divides the rocks between the trachytes and the andesites into two series—the trachyandesites and the trachydolerites, using the former term in a more restricted sense than in his earlier papers, and without the previously employed hyphen. The Sierra Nevada latites would fall most nearly within his trachydolerite series, although not the strict equivalents of any of its individual members. Whether some such single term as that here proposed shall be used to designate the rocks midway between the trachytes and andesites, or whether it will be found practicable to divide them into two series as Washington has done, may, as the latter suggests in a slightly different connection, be left to the winnowing action of time and usage.

Digitized by Google

Digitized by Google

	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.	XXVIII.	XXIX.	XXX.	XXXI.	XXXII.	XXXIII.	XXXIV.
SiO_2	58.47	60.97	57.29	60.89	52.16	52.53	52.81	54.20	54.42	57.66	58.05	58.98	61.72	61.73
TiO_2	.51		.72	.49			.71	.40	.80					
Al_2O_3	18.80	20.92	18.45	17.14	22.11	19.48	15.66	15.73	14.28	17.23	17.71	17.34	13.57	17.45
Fe_2O_3	3.34	3.81	4.38	3.32	8.58	11.07	3.06	3.67	3.32	7.28	8.29	3.44	7.60	5.94
FeO	2.64		1.20	.95			4.76	5.40	4.13					
MnO	.18		trace	.09			trace	.70	.10				.33	
MgO	2.69	.29	2.08	1.16	2.64	1.53	4.90	3.40	6.12	2.20	2.07	1.64	3.33	2.29
CaO	6.60	.14	3.57	3.58	8.61	6.61	7.57	8.50	7.72	5.32	5.81	8.64	5.88	4.52
BaO	.09						.24		.32					
Na_2O	3.58	5.03	4.43	4.54	3.35	2.71	3.60	3.07	3.44	3.41	2.93	3.41	3.12	3.12
K_2O	2.01	8.88	5.43	5.71	2.00	3.17	4.84	4.42	4.22	4.61	3.24	5.34	3.37	3.88
P_2O_5	.22		.46	.27			.75	.50	.59					
H_2O	[1] 1.92 [2] 1.14	.83	2.18	1.61	.80	2.34	[1] .93 [2] 1.16	.50	[1] 1.38 [2] 1.22	.70	1.34	1.66	.95	1.16
	SrO .05 Li_2O, tr.		NiO .12	NiO .19			SrO .09 Li_2O, tr. Cl .07 Fl, tr. SO_3, tr.		SrO .13 Li_2O, tr.	CO_2 .76				
Total	100.19	100.42	100.31	99.94	100.25	99.44	100.24 .02 100.22	100.50	100.19	99.17	99.49	99.85	99.43	100.09
Specific gravity		2.605												

[1] Above 110°.

[2] Below 110°.

Digitized by Google

Comparative table of chemical analyses.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.
SiO_2	55.44	55.69	56.19	56.76	56.78	57.97	58.67	59.41	59.43	59.88	60.03	60.88	61.09	61.44	61.93	62.33	63.17	63.49	65.81	59.81
TiO_2	.16	trace	.69	.....	1.15	.....	.....	.01	1.38	.....	.....	.....	.....	.....	.....	1.05	.....	trace	.54	.....
Al_2O_3	18.60	19.08	16.76	16.69	16.86	17.65	15.07	17.92	16.68	.....	17.05	16.19	.....	17.08	18.47	17.35	17.15	18.40	15.11	17.18
Fe_2O_3	2.09	4.07	3.05	2.07	3.56	.63	.....	1.71	2.54	.....	1.83	5.37	.....	3.67	1.93	2.98	2.84	2.44	1.85	} 5.99
FeO	4.48	3.26	4.18	6.95	2.93	7.50	8.35	2.40	3.48	.....	4.15	1.58	.....	2.42	2.23	1.63	1.31	1.09	1.40	
MnO	.....	trace	.10	.....	.....	.09	.....	.....	trace	.....	.09	.....	.....	.....	.....	.08	.....	.16	.....	.....
MgO	4.75	3.41	3.79	1.63	3.41	1.71	2.97	2.99	1.84	.....	1.12	2.96	.....	1.14	2.66	1.05	2.17	.66	.37	2.27
CaO	6.75	6.87	6.53	6.01	6.57	5.53	8.07	4.65	4.09	5.09	6.58	5.88	4.94	6.21	4.31	3.23	4.17	2.30	1.98	5.25
BaO	.....	.....	.19	.....	.....	.....	.....	.....	.14	.....	.....	.....	.....	.....	.....	.24	.....	.....	.10	.....
Na_2O	1.79	2.89	2.53	2.43	3.19	1.50	3.36	2.63	3.72	3.90	2.31	3.11	3.69	4.06	2.92	4.21	3.08	5.70	2.59	3.13
K_2O	6.63	4.41	4.46	4.67	3.48	5.31	3.50	5.60	5.04	5.06	5.12	3.95	5.27	3.86	3.92	4.46	4.19	4.62	5.24	4.67
P_2O_5	trace	.....	.55	.47	.42	.42	.....	.87	.58	.....	.42	.....	.....	.....	.....	.29	.....	trace	.23	.....
CO_2	.....	.....	.....	.....	.18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	trace	.....	.....
H_2O above 110°	} .25	.17	{ .66	.....	1.21	.....	} .82	1.30	{ .72	}	.....	.98	.....	2.04	2.28	{ .75	} 2.51	1.04	.....	.....
H_2O below 110°			{ .34	.....	.15	.....			{ .27							{ .44				
Ig	.....	.....	.....	2.44	.....	1.82	.....	.....	.....	.....	1.42	.....	.....	.....	.....	.....	.....	.....	.....	.....
			SrO, t. Li_2O, t.						ZrO_2 .08 SrO, tr. Cl .05							SrO .44 Li_2O, tr. FeS_2 .08 C .11				
Total	100.75	99.85	100.02	100.22	99.89	100.13	100.81	99.49	100.04	.....	100.12	100.70	.....	101.92	100.65	100.33	100.59	99.90	.....	
Specific gravity	2.70	.....	.....	2.47	2.67	2.451	2.765	.....	.....	.....	2.543	2.640	.....	.....	2.601	.....	.....	.....	2.38	

Digitized by Google

	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.	XXVIII.	XXIX.	XXX.	XXXI.	XXXII.	XXXIII.	XXXIV.
SiO_2	58.47	60.97	57.29	60.89	52.16	52.53	52.81	54.20	54.42	57.66	58.05	58.98	61.72	61.73
TiO_2	.51		.72	.49			.71	.40	.80					
Al_2O_3	18.80	20.92	18.45	17.14	22.11	19.48	15.66	15.73	14.28	17.23	17.71	17.34	13.57	17.45
Fe_2O_3	3.34	3.81	4.38	3.32	8.58	11.07	3.06	3.67	3.32	7.28	8.29	3.44	7.60	5.94
FeO	2.64		1.20	.95			4.76	5.40	4.13					
MnO	.13		trace	.09			trace	.70	.10				.33	
MgO	2.69	.29	2.08	1.16	2.64	1.53	4.99	3.40	6.12	2.20	2.07	1.64	3.33	2.29
CaO	6.60	.14	3.57	3.58	8.61	6.61	7.57	8.50	7.72	5.32	5.91	8.64	5.88	4.52
BaO	.09						.24		.32					
Na_2O	3.58	5.03	4.43	4.54	3.35	2.71	3.60	3.07	3.44	3.41	2.93	3.41	3.12	3.12
K_2O	2.01	8.88	5.43	5.71	2.00	3.17	4.84	4.42	4.22	4.61	3.24	5.34	3.37	3.88
P_2O_5	.22		.46	.27			.75	.50	.59					
H_2O	[1] .92 [2] .14	.83	2.18	1.61	.80	2.34	[1] .93 [2] .16	.50	[1] .38 [2] .22	.70	1.34	1.66	.95	1.16
	SrO .05 Li_2O, tr.		NiO .12	NiO .19			SrO .09 Li_2O, tr. Cl .07 Fl, tr. SO_3, tr.		SrO .13 Li_2O, tr.	CO_2 .76				
Total	100.19	100.42	100.31	99.94	100.25	99.44	100.24 .02 100.22	100.50	100.19	99.17	99.49	99.85	99.43	100.09
Specific gravity		2.605												

[1] Above 110°.

[2] Below 110°.

Digitized by Google

I. Ciminite, Fontana Fiescole, Viterbo, Italy. Jour. Geol., Vol. IV, p. 849. Washington, analyst.

II. Biotite-vulsinite, Monte Santa Croce, Rocca Monfino region, Italy. Jour. Geol., Vol. V, p. 252. Washington, analyst.

III. Augite-latite (36 S. N.), Table Mountain, near Shaws Flat, Tuolumne County, Cal. Hillebrand, analyst.

IV. Olivine-bearing andesitic trachyte, Sassara, Italy. Klein, Neues Jahrbuch für Min., etc., B. B. VI, p. 7. Ricciardi, analyst.

V. Augite-latite (1422 S. N.), Table Mountain flow, 1½ miles east of Clover Meadow, Tuolumne County, Cal. Steiger, analyst.

VI. Trachyte (Klein) or vulsinite (Washington), Bolsena, Italy. Klein, Neues Jahrbuch für Min., etc., B. B. VI, p. 8. Ricciardi, analyst.

VII. Ciminite, Monte Cimino, Italy. Jour. Geol., Vol. IV, p. 849. Vom Rath, analyst.

VIII. Andesite, Cabezo Felipe, Cabo de Gata, Spain. Zeitschr. Deutsch. geol. Gesell., vol. 43, 1891, p. 719. Osann, analyst.

IX. Augite-latite (1419 S. N.), 4 miles southwest of Clover Meadow, Tuolumne County, Cal. Stokes, analyst.

X. Augite-latite (86 S. N.), Tuolumne County, Cal., 3 miles southeasterly from Big Trees. Turner, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 729. Fireman, analyst.

XI. Trachyte (Klein) or vulsinite (Washington), San Magno, Italy. Klein, Neues Jahrbuch für Min., etc., B. B. VI, p. 10. Ricciardi, analyst.

XII. Augite-andesite, Mount Pagos, near Smyrna, Asia Minor. Washington, Am. Jour. Sci., 4th series, Vol. III, p. 43. Washington, analyst.

XIII. Biotite-augite-latite (85 S. N.), Tuolumne County, Cal., 3 miles southeasterly from Big Trees. Turner, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 729. Fireman, analyst.

XIV. Trachyte, Gleichenberg, near Steiermark. Tschermaks mineral. Mittheil., 1887, p. 277. Smita, analyst.

XV. Augite-andesite, Kara Tash, near Smyrna, Asia Minor. Washington, Am. Jour. Sci., 4th series, Vol. III, p. 45. Washington, analyst.

XVI. Biotite-augite-latite (1420 S. N.), 4 miles southwest of Clover Meadow, Tuolumne County, Cal. Hillebrand, analyst.

XVII. Biotite-dacite, Pergamon, Asia Minor. Washington, Am. Jour. Sci., 4th series, Vol. III, p. 49. Washington, analyst.

XVIII. Sanidine-bearing andesite, Rosita Hills, Colo. Cross, Proc. Colo. Sci. Soc., 1887, p. 250. Eakins, analyst.

XIX. Vitrophyric latite (?) (1866 S. N.), just south of Mill Creek, Tuolumne County, Cal. Partial analysis. Steiger, analyst.

XX. Mean of the important constituents of the 19 preceding analyses.

XXI. Hornblende-pyroxene-andesite (72 S. N.). Downieville area, Sierra Nevada, Cal. Turner, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 731. Hillebrand, analyst.

XXII. Trachyte (domite), Puy de Dôme, Auvergne. Zirkel, Lehrbuch der Petrographie, II, p. 378. Lewinstein, analyst.

XXIII. Quartz-banakite, dike, near head of Stinkingwater River, Yellowstone Park region. Iddings, Jour. Geol., Vol. III, p. 947. Melville, analyst.

XXIV. Quartz-banakite, dike, locality and reference as above. Melville, analyst.

XXV. Monzonite, Predazzo, South Tyrol. Brögger, Eruptivgesteine des Kristiania-Gebietes, II. Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol. Kristiania, 1895, p. 25.

XXVI. Monzonite, Sasinathal, Predazzo. Brögger, loc. cit.

XXVII. Monzonite, Beaver Creek, Bearpaw Mountains, Mont. Weed and Pirsson, Am. Jour. Sci., 4th series, Vol. I, p. 357. Stokes, analyst.

XXVIII. Monzonite, Monzoni, S. Tyrol. Brögger, op. cit., p. 24. Schmelck, analyst.

XXIX. Monzonite, Yogo Peak, Montana. Weed and Pirsson, Am. Jour. Sci., 4th series, Vol. I, p. 357. Hillebrand, analyst.

XXX. Monzonite, Mulatto, Predazzo, S. Tyrol. Brögger, op. cit., p. 25.

XXXI. Monzonite, Malgola, Paedazzo, S. Tyrol. Brögger, loc. cit.

XXXII. Monzonite, Predazzo, S. Tyrol. Brögger, loc. cit.

XXXIII. Monzonite, Blansko, Mähren. Brögger, op. cit., p. 50.

XXXIV. Monzonite, Hodritsch, Hungary. Brögger, loc. cit.

Digitized by Google

THE EVIDENCE OF THE LAVA FLOWS AS REGARDS OROGENIC MOVEMENTS.

The length of the Table Mountain flow and its favorable position with reference to the present drainage system suggested the comparison of its grade profile with those of the Stanislaus River, including its North and Middle forks, shown in Pl. II. The upper curve in the diagram is that of the base of the Table Mountain flow. Below it are the curves of the main Stanislaus River with its two principal branches, the lower grade being that of the larger Middle Fork. All the profiles are projected upon a vertical plane parallel with the upper and lower edges of the map—a method which, while it exaggerates the actual grade of certain portions of the streams, has the advantage of referring them all to the standard of an ideal consequent stream running straight down the slope and allows the direct comparison of one with another.

The curves as drawn for the existing streams are dependent upon the accuracy with which the canyon contours are laid down on the topographic sheets, while the profile representing the bottom of the lava stream as now dissected is in general somewhat higher than the true bottom of the channel down which it flowed. But the possible error from both sources is probably not large enough to affect seriously the general results to be deduced from a diagram on the scale shown.

The most noticeable fact that appears upon a comparison of the different profiles is the remarkable regularity of the Neocene curve as compared with the curves of the present streams. When there is recalled the great variety of rocks upon which the Table Mountain latite rests, this even character of the curve indicates that the stream which the lava displaced had been highly successful in establishing itself upon a uniform grade. In contrast with this profile, the profiles of the modern streams show some irregularities. The curve of the North Fork is approximately parallel along its middle portion with that of the Middle Fork; but near its junction with the latter stream it becomes considerably steeper, probably on account of the fact that, owing to its greater volume, the Middle Fork has been able to corrade its channel more rapidly than the North Fork, so that the latter stream is at present being lowered near its mouth at a rate too rapid to allow of a corresponding compensation along its entire course. At its upper end, also, the curve of the North Fork departs from its parallelism with that of the Middle Fork, rising rather suddenly and becoming slightly convex. This is due, no doubt, to the weakening of the stream near this point by a splitting up into head-water ramifications which are individually too feeble to cut deep gorges. In the case of the Middle Fork there is no very decided convexity shown, as the stream is much longer and carries its gorge farther back into the range. It is interest-

Digitized by Google

ing to note that the profile of the Neocene channel also exhibits a slight convexity in the upper regions, as if it, like the North Fork, were approaching its former head-water drainage. But too little is known of the extent and distribution of the latites to the eastward to draw any valuable conclusion from this change in curvature.

The curves, as they stand, give evidence that the Neocene stream bed, down which a portion of the lavas flowed, records the work of a more nearly graded stream than either of its modern representatives, the Middle and North forks of the Stanislaus. It probably flowed, therefore, on a lower grade than the existent rivers, and the present difference of 2,500 feet between the bed of the Middle Stanislaus and the bottom of the Table Mountain flow in the region of the Dardanelles is less than the minimum amount of elevation of this portion of the Sierra slope since the date of the latitic eruptions. Moreover, the great regularity of the Neocene curve indicates that the elevation of this region was effected by a movement or movements which have resulted in at least a superficial resemblance to a simple block tilting, without deformation of the old surface sufficiently great to be appreciable by the methods here used. Lindgren,[1] on the other hand, in his interesting study of the Neocene, Yuba, and American rivers, farther north, found that the elevation was accompanied by deformation, whereby the Neocene channels, instead of showing the regular grade profiles of their modern representatives, appear "to be composed of two curves, with the convex side upward." As the district studied by Lindgren is some hundred miles north of that here described, there is no necessary conflict in the different results arrived at in the two fields.

The channel down which the latite flowed was, as has been shown in the preceding pages, cut during the volcanic period as a whole, and belongs in time with the "intervolcanic channels" of Lindgren, and is therefore younger than the channels of the Neocene Yuba and American rivers, which antedate the main volcanic eruptions. It therefore records only a fraction of the differential uplift during Neocene time. According to Lindgren, the intervolcanic channels of the region described by him exhibit the marks of an erosive activity similar to that of the present day, and are marked by strong grades in whatever direction they flowed.[2]

The Table Mountain channel seems, however, to have been of a slightly different class, and to have been occupied by a long consequent stream of more nearly uniform grade than the present rivers, indicating a considerable interval of erosion between the different andesitic eruptions. The fact that it, on the whole, follows the course of the present Stanislaus, or bisects the angle of its two main branches, indicates that the tilting of the slope has been substantially constant in direction since the beginning of Neocene time.

[1] Bull. Geol. Soc. America, Vol. IV, 1893, p. 297.
[2] Loc. cit, p. 295.

Digitized by Google

SUMMARY.

The contents of the preceding sections may be very briefly summarized as follows:

The area embraced by the map is a fairly typical transverse strip of the middle western slope of the Sierra Nevada, having been worn down to a rough peneplain during the interval between the close of the Juratrias and the beginning of the Miocene. During the Miocene the volcanic eruptions began, which, accompanied by elevation and tilting of the peneplain, lasted to the end of the Pliocene. The first eruptions were rhyolitic, followed by the laying down of a great cloak of andesitic breccias and tuffs. The deposition of the auriferous gravels both preceded and accompanied the deposition of the volcanic material.

The accumulation of the andesitic tuffs and breccias was interrupted by at least one period of considerable erosion, during which a long consequent stream, the predecessor of the present Stanislaus River, established its channel down the slope, cutting through the volcanic cover into the older truncated Bed-rock series along the greater part of its course, and ultimately attaining a very uniform grade. This stream was subsequently displaced by a heavy flow of augite-latite, the Table Mountain flow, which, coming from an as yet unknown source near the crest of the range, ran down the stream bed to the edge of the Great Valley, a distance of more than 60 miles. A second and thinner flow of biotite-augite-latite followed, attaining a greater lateral extent, but not reaching the length of the first flow. The third, or Dardanelle flow, of augite-latite closed the series of latitic eruptions. The volcanic period, as a whole, was brought to an end by fresh andesitic eruptions, as shown by andesitic breccias resting upon the latites, accompanied by a further tilting of the peneplain toward the southwest.

During Pleistocene time the present streams have dissected the Neocene lavas and tuffs, including the latite flows, and have deeply incised the Bed-rock series of Juratrias and older rocks.

The Sierra Nevada latites are mineralogically closely related to ordinary andesites, but chemically they stand between the andesites and the trachytes. They are higher in alkalies than the andesites; the potash is generally slightly in excess of the soda, and, *in the particular rocks described*, is present chiefly in the unindividualized glass when no biotite is present.

Rocks of this intermediate chemical composition are fairly widespread, but are characterized by considerable mineralogical variety. The name latite is proposed as a convenient designation for this entire group of effusive rocks standing chemically between the trachytes and the andesites, and corresponding to the plutonic monzonites of Brögger and possibly to some of the dike banakites of Iddings and the gauteite of Hibsch.

A comparison of the grade profiles of the Neocene stream, down which the latites flowed, with those of the present Stanislaus River, shows that the elevation of the crest of the Sierra Nevada in this region has been such as would be produced by a simple block-tilting without perceptible warping.

Digitized by Google

Digitized by Google

INDEX.

Page.

Agglomerate lava of Fritsch and Reiss, origin of structure of 43
Alkalies of latites, proportion of 10, 57
Altitude of the area studied 10
Analyses of rocks, tables of 58–59, 66–69
Andesite (sanidine-bearing), chemical analysis of 66
Andesitic breccia or tuff associated with latite, petrographic character of. 52–55
occurrence of 9, 12, 18, 20, 22, 23, 26
Andesitic trachyte, chemical analysis of. 66
Apatite of augite-latite, characters of 35, 47
"Aschen-structur" in rhyolitic tuff, occurrence of 56
Augite of augite latite, characters of 29, 31, 32, 34, 35, 36, 46, 47, 48
Augite of biotite-augite-latite, characters of 38, 39, 40
Augite andesite, chemical analysis of 66
Augite-latite, chemical analyses of 57–59, 66
columnar structure of 13, 17, 23, 24
columnar type of (figured) 30
occurrence of 14–26
petrographical characters of ... 27–37, 46–52
plate showing microsection of 34
spheroidal structure of 23
spheroidal type of (figured) 28
Banakites, characters of 65
Bed-rock series, characters of 11
Biotite of biotite-augite-latite, characters of 37, 37–38, 39
Biotite-augite latite, chemical analyses of 57–59, 66
eutaxitic structure in 38, 40, 42–44
flow structure in 40
green hornblende in 38, 39, 41
inclusions in 37, 38, 40–42
occurrence of 19–23, 25–27
petrographical characters of 37–46
plate showing thin section of 34
rocks from the Troad similar to 44
Biotite-dacite, chemical analysis of 66
Biotite-vulsinite, characters of 62–63
chemical analysis of 66
Brögger, W. C., cited 60
Chemical analyses of rocks, tables showing 58–59, 66–69
Ciminite, characters of 63
chemical analysis of 66
Cross, Whitman, cited 63
Dardanelle flow, petrographical characters of 46–52

Page.

Dardanelle latite, Asiatic rock resembling 50
petrographic characters of 46–52
Dardanelle type of lava, character and occurrence of 14
Dardanelles, description of 13, 24–36
views of (plates) 14, 32
Diller, J. S., cited 11, 44, 56
Domite, chemical analysis of 67
Drainage of the region, character of 12–13
Elevation of the area studied 10
Erba, Luigi dell', cited 43
Erosion of the region, character of. 11, 14, 21, 26
Eutaxitic structure, characters of 42–43
Eutaxitic structure in biotite-augite-latite, figure showing 34
occurrence of 38, 40, 42–44
Flow structure in biotite-augite-latite 40
Fusulina, occurrence of 18
Gauteite, a possible dike equivalent of the latites 65
Glass in Sierra Nevada latites, character of 49
Globulites in Sierra Nevada latites, character of 48–49
Granite, use of term 13
Green hornblende in biotite-augite-latite, occurrence of 38, 39, 41
Groundmass of augite-latite, characters of 29–30, 30, 35, 48–49
Groundmass of biotite-augite-latite, characters of 37, 38, 41
Hibsch, J. E., cited on gauteite 65
Hornblende of biotite-augite-latite, characters of 38, 41
Hornblende-pyroxene-andesite, chemical analyses of 67
Iddings, J. P., cited 62, 65
Iddingsite in olivine-basalt, occurrence of 52–53
Inclusions in biotite-augite-latite .. 37, 38, 40–42
Jaggar, T. A., cited 51
Kemp, J. F., cited 43
Klein, J. F. C., cited 61
Küch, R., cited 43
Labradorite of augite-latite, characters of .. 29, 30, 31, 32, 34, 35, 36, 46, 47, 48, 50, 51
Labradorite of biotite-augite-latite, characters of 41
Latite, derivation of name 10, 64
petrographical characters of 27–37
Latite (vitrophyric), chemical analysis of 66

Digitized by Google

Page.

Latites, alkali content of 10, 57
character of glass in 49
character of globulites in 48-49
chemical composition of 57-59, 66
classification of 59-68
compared with vulsinites 62, 64
distinctive chemical features of 10
mineralogical variation in 62, 64
occurrence and distribution of 14-27
petrography of 27-46
plate showing microsections of 34
Lawson, A. C., cited 52
Lévy, Michel, cited 42
Magnetite of biotite-augite-latite, characters of 38, 40
Monzonites, chemical analyses of 67
relations of latites to 65
Olivine of augite-latite, characters of 29, 30, 31, 32, 34, 35, 36
Olivine of Dardanelle lava, characters of 46, 47, 50, 51
Olivine-basalt associated with latite, analysis of 58-59
iddingsite in 52-53
occurrence of 24-25
petrographical characters of 52-53
Olivine-bearing andesitic trachyte, chemical analysis of 66
Orogenic movements, evidences of the lava flows concerning 69-70
Orthorhombic pyroxene of biotite-augite-latite, occurrence and characters of 30, 40-41, 42
Osann, A., cited 63
Peneplain of the Sierra Nevada, features of 11-12, 14, 21, 22, 26
Peperino, characters of 44
Physiography of the region, general outline of 10-14
Piperno, supposed origin of structure of .. 43
Piperno structure, figure of latite showing 34
Plagioclases of augite-latite, characters of 28, 29, 31, 32, 35, 47, 48, 51

Page.

Plagioclases of biotite-augite-latite, characters of 37
Pyroxene (orthorhombic) of biotite-augite-latite, characters of 40-41, 42
Quartz-banakite, characters of 65
chemical analyses of 67
Ransome, F. L., cited 23, 52
Reiss (Fritsch and) cited 42
Rhyolite associated with latite, characters of 55-56
occurrence of 24
Rhyolitic tuff associated with latite, characters of 56
Ricciardi, L., reference to chemical analysis by 61
Rosenbusch, H., cited 29, 43
Sanidine-bearing andesite, chemical analysis of 66
Smith, G. O., cited 56
Smith, W. S. T., cited 52
Spheroidal structure in augite-latite, occurrence of 28
Stanislaus River, areas of latite along 17-18
map of portion of drainage basin of .. 12
Table Mountain, views of lava flow of . 20, 22, 24
Table Mountain type of lava, character and occurrence of 14-20, 21, 23
petrographical characters of 27-37
Trachytes, chemical analyses of 66, 67
Trask, J. B., cited on rocks of Tuolumne Table Mountain 15-16
Tuffs associated with latite, characters of . 52-57
Tuolumne Table Mountain, features of .. 15-17
Turner, H. W., cited 27, 30
letter of transmittal by 7
Vulsinite, characters of 61, 62
chemical analyses of 66
Washington, H. S., cited 18, 30, 44, 50, 52, 58, 61, 62, 63, 65
Whitney, J. D., cited 12, 16-17
Wichmann, A., cited on piperno structure of East Indian andesite 43
Wolff, J. E., acknowledgments to 10
Zirkel, F., cited 29, 43, 61, 63

Digitized by Google

DEPARTMENT OF THE INTERIOR

ABJ 3 1936

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 90

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

REPORT OF WORK DONE

IN THE

DIVISION OF CHEMISTRY AND PHYSICS

MAINLY DURING THE

FISCAL YEAR 1890-'91

FRANK WIGGLESWORTH CLARKE, CHIEF CHEMIST

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Letter of transmittal	9
On the constitution of certain micas, vermiculites, and chlorites. By F. W. Clarke and E. A. Schneider	11
New analyses of uraninite. By W. F. Hillebrand	22
On the isomorphism and composition of thorium and uranous sulphates	26
I. Chemical discussion. By W. F. Hillebrand	26
II. Crystallographic discussion. By W. H. Melville	31
Powellite—calcium molybdate: A new mineral species. By W. H. Melville	34
Mineralogical notes. By W. H. Melville	38
Natrolite from Magnet cove, Arkansas	38
Tourmaline from Nevada county, California	39
Spessartite garnet from Llano county, Texas	39
Bismuthinite from Sinaloa, Mexico	40
New analyses of astrophyllite and tscheffkinite. By L. G. Eakins	41
Two new meteorites. By L. G. Eakins	45
I. Meteoric iron from Pulaski county, Virginia	45
II. Stone from Washington county, Kansas	45
On the action of phosphorus oxychloride on the ethers and chlorhydrines of silicic acid. By H. N. Stokes	47
On the colloidal sulphides of gold. By E. A. Schneider	56
Miscellaneous analyses	62
Three minerals from Colorado	62
Yellow smithsonite from Arkansas	62
Rocks and clays from the zinc region of Missouri and Kansas	63
Two feldspars	65
Six sandstones	65
Seven marbles and dolomites	66
Nine rocks from Maryland	66
Eruptive rock from Kentucky	67
Four granites from Missouri	68
Three rocks from Minnesota	68
Rocks from Colorado	69
Rocks from Montana	70
Rocks from Arizona	72
Rock from Eureka, Nevada	72
Rocks from California	73
Sinter from Queensland	74
Two clays from Florida	74
Iron ores from West Virginia	74
Coal and coke from West Virginia	75
Two coals from Utah	75

Digitized by Google

Digitized by Google

ILLUSTRATIONS.

		Page.
FIG. 1.	Crystalline form of uranium sulphate	32
2.	Crystalline form of uranium-thorium sulphate	32
3.	Crystalline form of powellite	35

Digitized by Google

Digitized by Google

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
Washington, D. C., January 1, 1892.

SIR: In accordance with established usage, this bulletin, like its predecessors, bulletins 9, 27, 42, 55, 60, 64, and 78, contains a record of work done in the division of chemistry and physics during a fiscal year. It is, however, incomplete in certain respects; for unfinished investigations are not described, and the larger researches are reserved for independent publication. The physical studies of Dr. Barus, for example, and the work of Dr. Chatard upon the Florida phosphates, will appear in separate form; and many analyses of value which have been made in the chemical laboratory are to be published in the geological reports with which they properly belong. The bulletin, however, in spite of omissions, gives a fair idea of the range and variety of work done in the chemical laboratory.

F. W. CLARKE,
Chief Chemist.

Hon. J. W. POWELL,
Director.

Digitized by Google

Digitized by Google

WORK DONE IN THE DIVISION OF CHEMISTRY AND PHYSICS IN 1890-'91.

ON THE CONSTITUTION OF CERTAIN MICAS, VERMICULITES, AND CHLORITES.

By F. W. Clarke and E. A. Schneider.

In a previous paper upon the constitution of the silicates,[1] we sought to establish some new lines of attack upon the problem, especially with reference to the mica and chlorite groups. The present communication is to be regarded as a continuation of the same research, and by essentially the same methods; although in some instances the experiments have been less elaborate, when elaborateness seemed to be unnecessary. Throughout the investigation the fundamental hypothesis that the minerals studied are substitution derivatives of normal salts has kept steadily in view; and, as we believe, it has been amply justified.

Of the so-called vermiculites, two only, jefferisite and kerrite, were considered in our former paper; and these were shown to be trihydrated micas, in which the original alkalies had been replaced by hydrogen. To these examples we now add several others; of which two varieties afford excellent checks upon the earlier work. The two minerals in question are an altered biotite from the zircon mine in Henderson county, N. C., and the protovermiculite from Magnet cove, Arkansas, described some years ago by König. The analyses, with itemized water determinations, are as follows:

	Henderson county.		Protovermiculite.	
	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.
SiO_2	38·18	·636	34·03	5·67
TiO_2	1·68	·021	undet.	.....
ZrO_2	none	.....	.....	.....
Al_2O_3	14·02	·138	14·49	·142
Fe_2O_3	13·02	·081	7·71	·048
FeO	2·22	·031	0·14	·002
MnO	0·38	·005	0·09	·001

[1] Bulletin No. 78.

Digitized by Google

	Henderson county.		Protovermiculite.	
	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.
MgO	14·62	·385	20·89	·522
CaO	0·17	·003	1·88	·034
BaO	0·06			
K_2O	5·40	·057		
Na_2O	0·48	·008		
H_2O, 105°	3·20	·178	11·23	·624
H_2O, 250°-300°	2·52	·140	4·55	·253
H_2O, above 300°	4·80	·267	5·41	·301
	100·75		100·42	
H_2O over H_2SO_4	3·20		11·34	

The analysis of protovermiculite agrees with that of König as well as could be expected, but is carried out somewhat more in detail. In its appearance the mineral was dark brown, broadly foliated, much decomposed, and very brittle. Before the blowpipe it exfoliates and fuses easily. The Henderson county mica was also brown, brittle, and decomposed, exfoliating when heated and fusing at the edges. Both minerals were examined optically by Mr. Waldemar Lindgren. The protovermiculite he describes as "yellowish, containing in arborescent forms between the plates a great deal of a deep yellow or reddish substance, probably hydroxide of iron. Angle of optical axes larger than usual. Slight pleochroism; thicker plates remain light between crossed nicols." Of the Henderson county mica he says—"contains no titanium mineral. Contains a few grains of a colorless, strongly double-refracting mineral of uncertain nature, possibly zircon. Plates nearly dark between crossed nicols. Angle of optical axes small, but distinctly observed." In the material selected for analysis the impurities noted by Lindgren were, so far as possible, removed.

The composition of each mineral reduces quite easily, in accordance with the methods followed in our former work, to a mixture of simple isomorphous types. The only uncertainties appear to be in connection with the loosely combined water, which is driven off below 300°. In the Henderson county mica we have the molecules

$$\begin{array}{cccc} /SiO_4\equiv MgK & /SiO_4\equiv H_3 & /SiO_4\equiv MgH & /O\rangle Mg \\ Al—SiO_4\equiv MgH & Al—SiO_4\equiv H_3 & Fe—SiO_4\equiv MgH & Fe—O \\ \backslash SiO_4\equiv Al & \backslash SiO_4\equiv H_3 & \backslash SiO_4\equiv Fe & \backslash SiO_4\equiv H_3 \end{array}$$

in the ratio $8:1:3\frac{1}{2}:3$. The loosely combined water is in the proper amount to monohydrate the four molecules; but its actual distribution is uncertain. In the subjoined table monohydration is provisionally assumed. In the protovermiculite we have the three molecules

$$\begin{array}{ccc} /SiO_4\equiv H_3 & /O\rangle Mg & /O\rangle Mg \\ Al—SiO_4\equiv H_3 & Al—O & Fe—O \\ \backslash SiO_4\equiv H_3 & \backslash SiO_4\equiv H_3 & \backslash SiO_4\equiv Al \end{array}$$

Digitized by Google

each plus three molecules of water, in the ratio 14:6:9. As in the case of jefferisite and kerrite, the three molecules of loosely combined water are unlike, two being given off over sulphuric acid and the third retained rather more tenaciously.

Reducing the original analysis to 100 per cent, uniting all similar oxides to similar type, reckoning FeO as MgO, Na_2O as K_2O, TiO_2 as SiO_2, etc., we get the following comparison between observation and theory:

	Henderson county.		Protovermiculite.	
	Found.	Calc.	Found.	Calc.
SiO_2	39·70	39·90	34·10	34·18
Al_2O_3	14·12	14·25	14·52	14·78
Fe_2O_3	13·11	13·15	7·72	7·20
MgO	16·32	17·08	22·41	22·79
K_2O	6·17	6·17	.....	.....
H_2O, essential	4·83	4·87	5·43	5·40
H_2O, hydration	5·75	4·58	15·82	15·65
	100·00	100·00	100·00	100·00

These results, taken in connection with our work on jefferisite and kerrite, and with the mica theory upon which all our formulæ are based, are exceedingly suggestive. Kerrite is essentially a trihydrated hydrophlogopite. Protovermiculite is the same substance, commingled with a trihydrated hydroclintonite, in the ratio 1:1 very nearly. Jefferisite is a similar mixture of hydrobiotite and hydroclintonite, also trihydrated, and in the ratio 1:1. The Henderson county mica is essentially a biotite, about half way transformed into a vermiculite, and is interesting as a transition product. The hydration of its several admixed molecules is naturally uncertain. At an early date we hope to imitate experimentally the process by which a mica becomes transformed into its corresponding vermiculite.

But although the above-named minerals appear to be very simple in their structure and relationships, a like simplicity does not characterize all of the vermiculites. In some members of the group there seem to be a small admixture of chloritic molecules, and it is even probable that many intermediate stages between mica and chlorite may exist. As bearing upon this question we have a series of vermiculitic minerals from Chester and Delaware counties, Pennsylvania, some of which have already been studied by Cooke, Gooch, Leeds, and others, while some have escaped examination hitherto. To begin with, we may consider the hallite, from Nottingham, Chester County, and the vermiculites from Lenni (not Lerni), Delaware County. The hallite, received through the kindness of Mr. W. W. Jefferis, was dark bluish green, and agreed perfectly with the published descriptions. The Lenni mineral, partly from the collection of the late Isaac Lea, and partly gath-

Digitized by Google

ered in the field by one of us, is represented by several varieties, which in a large series of specimens are seen to shade into each other. Three varieties were examined: one, silver white, resembling outwardly an ordinary mica; a second, bronzy brown, like jefferisite; and the third, dark green, similar to clinochlore. All four substances were examined microscopically by Mr. Lindgren, who reports as follows:

A. HALLITE.

Corresponds exactly to Cooke's description.[1] Contains spear-shaped rhombic or more rarely hexagonal inclusions of a dark brown mineral distributed along lines cutting each other at angles of 60° and 120°. Asterism apparently uniaxial, although the plates sometimes show slight double refraction between crossed nicols.

B. WHITE LENNI.

Silvery luster in large fragments. Thin foils colorless, thicker yellowish and yellowish brown. Substance pure; no inclusions, except small crystals of feldspar (?) once observed. Thin lamellæ very faintly double refracting, in streaks and patches. Interference figure a cross, not dissolved. Crossing lines on surface marked quite well.

C. BROWN LENNI.

Brownish yellow, similar to biotite. Hexagonal line system not very marked. Thin plates yellowish to deep yellowish brown. Substance pure, except containing in small foils and arborescent forms some Fe_2O_3. Thicker plates do not extinguish in any position between crossed nicols. Angle of optical axes very small.

D. GREEN LENNI.

Thin lamellæ colorless, thicker light to deep green. No inclusions. Thin lamellæ faintly double refracting; in thicker plates the cross is dissolved into distinct hyperbolas. Does not get dark in any position between crossed nicols. Pleochroism notable in sections oblique to the cleavage plane. Fibers deep green when parallel to the principal plane of the microscope, light green when perpendicular to it. No line systems noted on the surface.

Upon analysis, the four minerals gave the subjoined results, with the water determinations itemized as usual:

[1] Proc. Am. Acad. Arts. and Sciences, 1874, vol. 9, p. 35.

Digitized by Google

	A. Hallite.	B. Lenni 1.	C. Lenni 2.	D. Lenni 3.
SiO_2	35·54	36·72	35·09	34·90
TiO_2	undet.	0·18	0·58	0·10
Al_2O_3	9·74	10·06	12·05	10·60
Fe_2O_3	9·07	5·37	6·67	8·57
Cr_2O_3	.....	0·26	0·46	0·23
FeO	0·28	0·12	0·11	0·22
MnO	0·25	0·31	0·27	0·17
NiO	0·16	0·20	0·20	0·19
MgO	30·05	29·40	27·62	28·21
BaO	.....	.....	trace	.....
H_2O, 105°	2·64	6·40	5·70	4·99
H_2O, 250°–300°	1·23	2·68	1·98	1.60
H_2O, red heat	10·91	8·69	9·22	9·88
	99·87	100·39	99·95	99·66
Loss over H_2SO_4	undet.	6·92	5·84	5·21

In these analyses we at once see that the combined water is mostly in excess of the crystalline water, and that the formulæ deduced must be correspondingly modified. The molecular ratios are as follows:

	A.	B.	C.	D.
SiO_2	·592	·614	·591	·583
R_2O_3	·152	·134	·163	·159
RO	·760	·744	·698	·712
H_2O, fixed	·606	·483	·512	·549
Aq.	·215	·504	·427	·366

In order to learn something as to the distribution of the hydroxyl indicated by these ratios, resort was had to the process of heating in dry, gaseous, hydrochloric acid, as described in our former paper. From this test, however, the brown Lenni vermiculite was omitted, as being intermediate in its character between the white and the green. Each experiment was made at the temperature 383°–412°.

	A.	B.	D.
Hours heated	16½	16	17
R_2O_3 removed	3·42	1·08	1·56
MgO removed	8·09	6·30	6·57
Molec. ratio MgOH	·202	·158	·164

Here it is assumed, on the grounds of our former work, that the magnesia rendered soluble by gaseous HCl is present as MgOH. Representing this by the symbol R′, the three vermiculites give the following empirical formulæ:

Hallite ..... $R'''_{304}R''_{558}R'_{202}H_{1010}(SiO_4)_{592}O_{436}$, 215 aq.
White Lenni ..... $R'''_{366}R''_{588}R'_{158}H_{808}(SiO_4)_{614}O_{259}$, 504 aq.
Green ..... $R'''_{318}R''_{548}R'_{164}H_{934}(SiO_4)_{583}O_{408}$, 366 aq.

Digitized by Google

These reduce at once, subject to small uncertainties as to hygroscopic water, to mixtures of molecules of the hydroclintonite and hydro-phlogopite types, with small amounts of chloritic compounds $Mg(SiO_4)_2(MgOH)_6$ and $Mg_2(SiO_4)_2H_4$. Upon this basis the three minerals become:

			Molecules.
Hallite	$Al(SiO_4)_3Mg_3H_3$	3 aq	7
	$AlO_2MgSiO_4H_3$		18
	$Mg(SiO_4)_2(MgOH)_6$		3
	$Mg_2(SiO_4)_2H_4$		2
White Lenni	$Al(SiO_4)_3Mg_3H_3$	3 aq	6
	$AlO_2MgSiO_4H_3$		5
	$Mg(SiO_4)_2(MgOH)_6$		1
Green Lenni	$Al(SiO_4)_3Mg_3H_3$	3 aq	4
	$AlO_2MgSiO_4H_3$		8
	$Mg(SiO_4)_2(MgOH)_6$		1

The actual ratios observed were slightly more complex, but the foregoing expressions accord well with the analyses. Here, as previously, we may reduce the analyses to typical form and 100 per cent, reckoning Fe_2O_3 as Al_2O_3, etc. The comparison is as follows:

Analyses reduced.

	A (Hallite).	B (White).	D (Green).
SiO_2	36·93	37·56	36·33
Al_2O_3	16·13	14·92	16·83
MgO	31·58	30·41	29·44
H_2O	11·34	8·86	10·26
Aq	4·02	9·25	6·84
	100·00	100·00	100·00
MgO in MgOH	8·09	6·30	6·57

Calculated.

	A.	B.	D.
SiO_2	36·47	38·11	36·61
Al_2O_3	15·82	14·25	16·97
MgO	31·75	30·49	29·95
H_2O	11·27	8·92	10·47
Aq	4·69	8·23	6·00
	100·00	100·00	100·00
MgO in MgOH	8·93	6·10	6·66

When we consider the nature of the vermiculites, as products of alteration, the agreement here shown is fully as close as could be expected. Many well crystallized minerals, fresh and unaltered, are less simply interpreted.

On the 19th of February, 1891, Prof. Tschermak read before the Vienna Academy a paper on the chlorite group,[1] in which he referred

[1] Sitzungsb. Wien. Akad., 1891, vol. 100, p. 31.

Digitized by Google

certain vermiculites to that class of minerals. He also put forth some views concerning the constitution of the chlorites, which, however, we can not discuss in the present communication.

One fundamental molecule, regarded by Tschermak as a constituent of most chlorites, we may adopt for present purposes, under slightly different structural form from his. This is the "amesite substance," $SiAl_2Mg_2H_4O_9$, written by Tschermak $SiAl_2H_2O_7(MgOH)_2$. In default of experimental evidence this may be transformed into $OMg_2SiO_4(AlH_2O_2)_2$, when it becomes part of a natural chloritic series parallel with the micas, thus:

Normal orthosilicate.....	$Al_4(SiO_4)_3$	$Mg_4(SiO_4)_2$
Whence we derive—	Micas.	Chlorites.
	$Al_3(SiO_4)_3R'_3$	$Mg_3(SiO_4)_2R'_2$
	$Al_2(SiO_4)_3R'_6$	$Mg_2(SiO_4)_2R'_4$
	$Al(SiO_4)_3R'_9$	$Mg(SiO_4)_2R'_6$
	$Al{-}O{<}^{O}_{SiO_4}{>}R''=R'_3$	$O{<}^{Mg}_{Mg}{>}SiO_4=R'_2$

In other words, the "amesite substance" in our chlorite series is the basic equivalent of the clintonite molecule among the micas, and is applicable to the solution of certain obscure problems. Some of the vermiculites, as Tschermak suggests, are probably chlorites, and two examples have come under our notice in which this view is partly sustained. Both were originally received from Mr. Jefferis; one from the corundum mine at Newlin, Chester county, Pa., and the other from Middletown, Delaware county, in the same state. The Newlin mineral was dull green, and much resembled culsageeite both outwardly and optically. The Middletown vermiculite was bright golden yellow; strongly exfoliating before the blowpipe and fusible on the edges. It was found upon the farm of Mr. James Painter, whence Mr. Jefferis named it provisionally "painterite," a name which seems also to have been applied to a peculiar brownish, waxy, feldspathic matrix in which the broad golden laminæ were imbedded. A second sample of it was later collected by one of us. According to an optical examination by Mr. Lindgren, the matrix of the "painterite" is a mixture of plagioclase feldspar, probably labradorite, with serpentine. Concerning the three vermiculites he makes the following notes:

A. FROM NEWLIN.

Hexagonal surface marking quite distinct. Bluish green. In thin lamellæ colorless to pale bluish green. Substance pure. The greenish color is distributed somewhat unevenly through the mineral. Axial angle unusually large, being at least 25°.

B. "PAINTERITE" RECEIVED FROM JEFFERIS.

Yellowish brown. Strong hexagonal marking on the surface. Thin lamellæ colored yellowish by numerous interpositions of a very finely

Digitized by Google

distributed substance, probably hydroxide of iron. Even thin foils show slight double refraction between crossed nicols, and do not extinguish in any position. Angle of optical axes small but distinct.

C. "PAINTERITE" COLLECTED BY SCHNEIDER.

Surface marking quite distinct. Contains a great number of small foils of Fe_2O_3, and also some yellowish, finely divided substance. Not enough materially to affect the analysis. Otherwise like B. Analysis as follows: A, Newlin; B, painterite from Jefferis; C, painterite collected by Schneider; D, matrix of painterite.

	A.	B.	C.	D.
SiO_2	31·23	34·86	33·95	52·47
TiO_2	.....	trace	trace	none
Al_2O_3	17·52	11·64	12·52	21·72
Cr_2O_3	0·14	.....	.....	.....
Fe_2O_3	4·70	3·78	4·40	1·23
FeO	1·20	0·20	0·20	0·17
MnO	0·20	.....	.....	.....
NiO	0·33	0·14	0·23	.....
MgO	31·36	31·32	30·56	9·26
CaO	.....	0·07	none	3·25
K_2O	.....	.....	.....	0.63
Na_2O	.....	.....	.....	5·09
H_2O, 105°	1·08	1·64	1·56	1·14
H_2O, 250°-300°	0·40	1·03	0·59	.....
H_2O, ignition	12·15	15·75	16·46	4·74
	100·31	100·43	100·47	99·70

Upon treating the three vermiculites with gaseous hydrochloric acid at 383°–412°, the following results were obtained:

	A.	B.	C.
Hours heated	8	12½	19
R_2O_3 removed	1·09	·80	·78
MgO removed	5·86	8·26	9·56
Molecular ratio MgOH	·146	·207	·239

The molecular ratios are:

	A.	B.	C.
SiO_2	·520	·581	·566
R_2O_3	·202	·138	·150
RO	·808	·789	·770
H_2O	·675	·875	·914
Aq	·080	·148	·119

Digitized by Google

In these examples the water (Aq.) expelled below 300° is so small in amount that it may be left out of consideration. Part of it undoubtedly represents hydrated molecules, which, however, are relatively so few in number that they may be for present purposes disregarded.

From the remaining ratios, writing MgOH as R′, the subjoined empirical formulæ are directly derived:

Newlin ..... $R'''_{404}\ R''_{652}\ R'_{146}\ H_{1304}\ (SiO_4)_{820}\ O_{978}$.
"Painterite" B ..... $R'''_{276}\ R''_{542}\ R'_{207}\ H_{1543}\ (SiO_4)_{561}\ O_{709}$.
"Painterite" C ..... $R'''_{300}\ R''_{531}\ R'_{239}\ H_{1589}\ (SiO_4)_{566}\ O_{763}$.

Reduced to structural form, these give less satisfactory results than the previously considered vermiculites. The Newlin mineral may be regarded as nearly a hydroclintonite, $AlO_2MgSiO_4H_3$, with an admixture of an amesite-like compound, $Mg_2OSiO_4(MgOH)_2$, in the ratio 4:1. In reality the mixture is more complicated and must contain other molecules. The "painterite" C is wholly chloritic, containing the amesite molecule $Mg_2OSiO_4(AlH_2O_2)_2$, with the molecules $Mg(SiO_4)_2(MgOH)_6$ and $Mg(SiO_4)_2H_6$, in the ratio 8:2:9. These compare with the actual analyses, reduced to typical form and 100 per cent, thus:

	Newlin.		"Painterite."	
	Found.	Calc.	Found.	Calc.
SiO_2	32·42	31·57	35·03	35·59
Al_2O_3	21·39	21·47	16·22	16·13
MgO	33·57	33·69	31·77	30·84
H_2O	12·62	13·27	16·98	17·44
	100·00	100·00	100·00	100·00
MgO in MgOH	6·09	8·42	8·56	9·49

The "painterite" B reduces less easily, but satisfies all the required conditions. It is like C, but contains other chloritic molecules in somewhat complex ratios. It must be remembered that all these minerals are *mixtures*, and the fact that they are reducible at all to simple expressions is a strong point in favor of the theory adopted for the chlorites and micas in general.

A very interesting example of the way in which the chloritic vermiculites approach the serpentines in composition and character has been furnished us by Mr. G. P. Merrill, of the U. S. National Museum. It was found by him at Old Wolf quarry, Chestnut hill, Easton, Pa., and is described by him as follows:

It occurs in the form of bright yellowish green inelastic scales of all sizes up to an inch in diameter, associated with a compact tremolite rock, which is here quarried and pulverized for use as a filler in paper manufacture. The character of the rock is greatly varied, but at the quarry opening the prevailing material is tremolite, more or less altered into serpentine, the vermiculite and other secondary products including calcite in both fibrous and granular forms.

Digitized by Google

The vermiculite, although occurring in plates of considerable thickness, readily separable into thin foliæ, never, so far as observed, shows good crystal outlines. Optically it is biaxial and negative, though the axial angle is small, basal plates in the thin section showing a black cross, which scarcely opens at all during the revolution of the stage. Cleavage plates a millimeter or more in thickness show plainly the biaxial character, though the figure is somewhat distorted. Dispersion, $\rho < v$.

The surface of the plates is at times plainly marked by sharp lines crossing at angles of 60° and 120°, and along which the mineral frequently separates readily. Before the blowpipe the mineral exfoliates and fuses readily on the edges to a thin glass.

According to Mr. Merrill this mineral is sometimes seen in cabinets labeled "talc;" and, indeed, in its appearance it resembles both talc and serpentine. Upon analysis the following results were obtained, the percentage of K_2O representing two identical determinations:

	Analysis.	Molecular ratios.
SiO_2	43·71	·728
Al_2O_3	3·59	·035
Fe_2O_3	0·90	·006
MgO	38·58	·964
K_2O	2·22	·023
Na_2O	0·13	·002
H_2O, 105°	0·46	.....
H_2O, 250°–300°	0·09	.....
H_2O, ignition	10·70	·594
	100·38	

Treated with dry, gaseous HCl at 383°–412° for 16½ hours, 4·36 per cent of magnesia became soluble, corresponding in molecular ratio to 109 mol. MgOH. Hence the mineral, although resembling serpentine in general composition, differs from the latter in its proportion of this molecular group.

Upon treatment with aqueous HCl, of specific gravity 1·12, a small portion remained undecomposed. Ten grammes of the mineral were therefore digested with the acid for three days on the water bath, and the residue was afterwards boiled out with a solution of sodium carbonate to remove liberated silica. The remaining residue, amounting to 3·10 per cent of the original material, was then analyzed separately and found to contain—

SiO_2	64·53
Al_2O_3, Fe_2O_3	2·03
MgO	33·04
	99·60

All the potash went into solution; whence it seems probable that no muscovite was present. The ratios of the insoluble residue agree very closely with those of talc, and we may therefore assume that mineral to be present as an impurity. Deducting from the molecular ratios

Digitized by Google

given above the quantity of talc indicated by experiment, we get for the empirical formula of the mineral the expression—

$$Al_{82}K_{50}Mg_{936}H_{1170}(SiO_4)_{695}O_{281},$$

which becomes, if the excess of oxygen is regarded as hydroxyl, with $(MgOH)_{109}$ as observed,

$$Mg_{829}K_{50}H_{839}(MgOH)_{109}(AlH_2O_2)_{82}(OH)_9.$$

The small excess of hydroxyl is probably due to undistributed errors of analysis, and may be added to the MgOH, bringing the latter to 118 and reducing the Mg to 820. Then, generalizing, by uniting all the univalent groups and atoms, we get as an ultimate formula—

$$Mg_{820}(SiO_4)_{695}R'_{1139},$$

which equals, almost exactly,

$$125\ Mg_3(SiO_4)_2R'_2 + 223\ Mg_2(SiO_4)_2R'_4,$$

a result in accordance with our serpentine-chlorite theory. The distribution of the several components of R′ is, however, not clear and remains to be ascertained. No other discussion of the analysis appears to give as satisfactory results as this, and we have tried several methods of reduction, representing various hypotheses.

One other mineral examined during this investigation remains to be noticed, a pale yellowish green mica collected by Mr. G. P. Merrill at a granite quarry in Auburn, Me., near where the Maine Central railroad crosses the Androscoggin river. It occurs in direct contact with ordinary, broadly foliated muscovite, sometimes forming marginal growths about the plates of the latter mineral, like lepidolite. Analysis gave:

SiO_2	46·54
Al_2O_3	34·96
Fe_2O_3	1·59
MgO	0·32
K_2O	10·38
Na_2O	0·41
F	none.
H_2O, 105°	0·71
H_2O, ignition	4·72
	99·63

This is the composition of muscovite, which the mica undoubtedly is. The case is interesting, however, as showing a secondary growth of muscovite on muscovite, with a marked difference in outward appearance between the two formations.

Digitized by Google

NEW ANALYSES OF URANINITE.

By W. F. Hillebrand.

Since the publication of a former paper on the occurrence of nitrogen in uraninite and on the composition of uraninite in general[1] no advance has been made toward clearing up the mystery surrounding the composition of that mineral, although considerable work has been done in certain directions, some of which is of sufficient interest to be produced later in a separate publication. In addition, several analyses of uraninité have been made, the material being in part from localities hitherto unrepresented by analytical data, and these form the subject of the present paper.

A first glance sufficed to show that the specimens were not fresh and that therefore analysis could throw no light on the ultimate composition of the mineral, but valuable data to be obtained as to the presence or absence of nitrogen and of the rare earths furnished ample excuse for the work.

No. 1*a* is a reanalysis of nivenite from Llano county, Tex., the material for which was kindly given by Mr. W. E. Hidden. It agrees in the main with the original analysis of this variety by Hidden and Mackintosh,[2] which is reproduced under 1*b*, and it confirms the presence of nitrogen, suspected but not proved by them. A small remnant of their original powdered sample gave me 0·52 per cent of nitrogen. In *a* the earths appear in slightly greater total amount than in *b* and they are more subdivided into groups and elements, which accounts fully for the difference between the atomic weights of the metals of the yttrium group of the two analyses. It was rendered certain by a second test that a group of earths whose sulphates are insoluble in potassium sulphate, other than those of Th, Zr, and Ce, is present.[3] A very satisfactory turmeric-paper reaction for zirconia was obtained in this analysis, as

[1] Am. Jour. Sci., 3d ser., vol. 40, p. 384; Bull. U. S. Geol. Survey, No. 78, 1889–'90, p. 43.

[2] Am. Jour. Sci., 3d ser., 1889, vol. 38, p. 481.

[3] It may be here remarked that the subdivision of the earths into the groups indicated by $(La, Di)_2O_3$ and $(Y, Er)_2O_3$ in all my former analyses should not be taken too literally. By the former are meant those earths insoluble in potassium sulphate and by the latter those soluble in that reagent.

Digitized by Google

also in that next following, which would go to show that the hypothetical ZrO_2 of several of my earlier analyses was probably in fact zirconia. The cause of the considerable loss shown by the analysis is not known. It may be mentioned that nivenite is more soluble than any uraninite heretofore examined by me, not even excepting cleveite. One hour sufficed for complete decomposition in very dilute sulphuric acid ($1H_2SO_4$ to $6H_2O$) at the temperature of boiling water.

	I.—Llano county, Tex.		II.—Marietta, S. C.	III.—Villeneuve P., Quebec, Canada.	IV.—Johanngeorgenstadt, Saxony.
	a. Hillebrand.	*b.* Hidden and Mackintosh.			
UO_2	44·17	46·75	*83·95	41·06	59·30
UO_3	20·89	19·89		34·67	22·33
ThO_2	6·69	7·57	1·65	6·41	
ZrO_2	0·34	.....	0·20	(†)	
CeO_2	0·34	.....	0·19	0·40	none.
La group	2·36	.....	2·05	1·11	
Y group	‡ 9·46	‡ 11·22	§ 6·16	‖ 2·57	
CaO	0·32	.....	0·41	0·39	1·00
PbO	10·08	10·16	3·58	11·27	6·39
H_2O	1·48	¶ 2·54	undet.	1·47	3.17
N	0·54	.....	undet.	0·86	0·02
SiO_2	** 0.46	.....	0·20	0·19	0·50
Insoluble	†† 1·47	1.22		0·13	.....
Fe_2O_3	0·14	0·58	trace.	0·10	0·21
Al_2O_3?	.....	.....	.....	.....	0·20
MgO	.....	.....	trace.	.....	0·17
Na_2O	.....	.....	trace.	.....	0·31
Bi_2O_3	.....	.....	.....	0·09	0·75
CuO	.....	.....	.....	.....	0·17
MnO	.....	.....	.....	.....	0·09
P_2O_5	.....	.....	.....	.....	0·06
As_2O_5	.....	.....	.....	.....	2·34
V_2O_5	.....	.....	.....	.....	
W_3O_8	.....	.....	.....	.....	0·75
MoO_2	.....	.....	.....	.....	
SO_3	.....	.....	.....	.....	0·19
	98·74	99·93	98·39	100·72	97·95
Sp. gr.	8·29	8·01	.....	.....	6·89

* As U_3O_8. † Atomic weight, 111·4. ‡ Atomic weight, 124·2. § Atomic weight, 113·6. The oxalates of this group were white, not pink like those in 1*a*, but the color of the ignited oxides was the same in both cases and very light. ‖ Atomic weight, 111·2, approximately. ¶ Ignition. ** From thorogummite. †† Mainly fergusonite.

No. II is from a new locality, Marietta, Greenville county, South Carolina, and the total amount found, a few small fragments, was kindly given by Mr. W. E. Hidden for examination. It was impossible to free the least altered portions from the yellow and orange alteration products with which they were intimately commingled; therefore the analysis represents the composition of a mixture. Unfortunately also the portion in which UO_2 and N were to be estimated was lost, but it was

Digitized by Google

seen that the mineral was very soluble and gave off considerable gas. From the preponderance of the yttrium group over the other rare earths the mineral is to be classed with nivenite and cleveite rather than with those varieties rich in thoria, a conclusion already foreshadowed by its ready solubility.

No. III is an analysis of uraninite from the Villeneuve mica mine, township of Villeneuve, Ottawa county, province of Quebec, Canada. To Mr. G. C. Hoffman, of the Canadian Geological Survey, who first recognized and reported this occurrence,[1] I am indebted for the material analyzed. It was evidently somewhat altered and was accompanied by oxidized alteration products. Hoffman gives the density of a piece as 9·055. Crystalline form was lacking, but it unquestionably belongs to the crystallized uraninites, being found, like most if not all of them, in coarse granite (pegmatite).

No. IV represents the composition of a specimen from Johanngeorgenstadt, in Saxony, received from Mr. A. Lösch, of St. Petersburg, through Mr. E. A. Schneider, of the U. S. Geological Survey. Notwithstanding the altered and crumbling character of the specimen it is proper to publish the analysis since the only one previously made that has come under my observation, by Pfaff in 1822, is very incomplete. By panning a very fair article as regards visible impurity was obtained. It is not known wherein the loss is to be sought. Like the great mass of the Bohemian mineral this showed no evidence of ever having been crystallized, and as in that also rare earths are absent, and also nitrogen, except for an uncertain trace.

From the analyses of uraninite thus far made it appears that the species may be broadly divided into two groups, the one of which is characterized by the presence of rare earths, the other by their absence. With the former group nitrogen appears to be invariably associated, while in the latter it is present, if at all, only in minute quantity. Besides these chemical differences there is one of another kind, for probably all varieties of the first group occur in more or less well defined crystals, while the members of the second group are generally, if not altogether, massive and free from crystalline form. These differences suggest naturally a dissimilarity of origin and environment. Examination shows that the manner of occurrence and the association of other minerals are different and in such a way as to render an unlike immediate origin probable. All of the rare earth uraninites, with exception of the zirconiferous variety from Black Hawk, Colorado, occur as an apparently original constituent of coarse granites (chiefly pegmatitic), while the others are evidently of secondary formation, as evidenced by their presence in metalliferous veins in more or less intimate association with numerous sulphides of silver, lead, cobalt, nickel, iron, zinc, copper, etc. The Colorado variety occupies an anomalous position as regards the two groups. I prefer to regard it provisionally as

[1] Annual Report Can. Geol. Surv., 1886, vol. 2, Report T, p. 10.

Digitized by Google

a member of the second group, where its mode of occurrence and want of crystalline form as well as small percentage of nitrogen seem to place it, although its zirconia and traces of other earths would admit it to the first.

Attention is called to the above points merely to show that the chemical and physical differences of the two groups may be susceptible of more simple explanation than would appear from the face of the analyses.

Digitized by Google

ON THE ISOMORPHISM AND COMPOSITION OF THORIUM AND URANOUS SULPHATES.

By W. F. Hillebrand and W. H. Melville.

I. CHEMICAL DISCUSSION, BY W. F. HILLEBRAND.

During the course of an extended investigation on uraninite it was often necessary to decompose the mineral in sealed tubes with sulphuric acid.[1] At first a deposit was generally observed on removing the tubes from the oven, the character of which depended on the concentration of the acid and the presence or absence of thoria in the mineral. In the absence of this earth it took the form of a greenish powder with a strong acid, and of bright green, brilliantly reflecting crystals when a weak acid was used, unless the ratio of liquid to mineral was sufficiently high in the latter case to prevent crystallization. As might naturally be supposed, these crystals were hydrated uranous sulphate. The best results as regards size of crystals were obtained with an acid containing one part of sulphuric acid to five or six of water, by volume. With about 100 parts by weight of such an acid to one of UO_2, it might pretty confidently be expected that no crystallization would take place.

In presence of thoria the green crystals still appeared, but they then contained thorium as well as uranium, and accompanying them was a beautiful white coherent spongy mass extending the length of the tube and consisting of a network of microscopic needles grouped in radiating bunches. This was likewise a double sulphate of uranium and thorium, resembling in every respect the deposit formed under similar conditions from a solution of thorium sulphate alone, except that when washed, dried, and compacted together there was a faint greenish tinge to it. Ordinarily the two forms of double salt appeared together, and it even seemed as if under favorable conditions, which have not yet been precisely determined, the crop of green crystals might be increased at the expense of the white deposit. At least on one occasion, when the heating was prolonged for several days, the latter gradually disappeared, while the former increased in size and number. The white deposit always preceded the green crystals, and, by regulation of the proportions of oxide and of acid and of duration of heating, it is possible in practice to obtain the former alone if desired.

In order to secure material for exact chemical and crystallographical determinations recourse was had to artificially prepared U_3O_8 and ThO_2,

[1] Bull. U. S. Geological Survey, No. 78, p. 43, 1889-'90.

Digitized by Google

by using which, either alone or mixed, in varying proportions, different products were obtained. Neither uraninite nor UO_2 is well adapted for this purpose, because of contamination of the crystals by sulphate of lead in the one case and by undissolved UO_2 in the other. Even when using U_3O_8 care must be taken to avoid a like result by fine pulverization and avoidance of excess of oxide compared with acid. So little soluble are the green crystals that over 50 per cent of the UO_2 in uraninite or U_3O_8 can generally be obtained as sulphate. Hence it follows that when UO_2 is to be estimated volumetrically care must be taken to use sufficient dilute acid to render impossible the formation of these crystals. The white spongy deposit is not a hindrance to exact estimation of UO_2 by potassium permanganate, for it dissolves readily in cold water, though with extreme slowness when once it has been compressed.

The green crystals were separated from their mother liquor in a Gooch crucible, without asbestus felt, with the aid of suction; they were at once washed with hot dilute sulphuric acid, then with alcohol, and finally with ether. They were allowed to dry thoroughly in the air and were analyzed in that condition. It was found by experiment that alcohol was practically without solvent action on the sulphates and that none of the water of crystallization was removed by it. If both forms of deposition occurred at one time the spongy one was first removed with great ease by two or three rapid washings with cold water, the network of fine needles being partly dissolved and partly carried through the holes in the crucible by the powerful suction, after which alcohol and ether were used as before. The results of analyses were as follows:

	I.		II.	
	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.
UO_2	49·18	1·00	48·40	1·00
ThO_2	3·59		5·58	
SO_3	32·08	2·05	31·27	1·96
H_2O	14·18	4·04	14.84	4·13
	99·03		100·09	

A sample of uraninite decomposed by dilute sulphuric acid in a tube at about 170° C. furnished the product whose analysis is given under I. An earlier and very similar analysis of another preparation may be found on p. 50 of the bulletin already cited. The loss is mainly if not altogether undetermined PbO from included $PbSO_4$, which accounts in part for the excess of SO_3 found. For No. II U_3O_8 and ThO_2 were taken in such proportion that there should be about six times as much UO_2 as of ThO_2. Inasmuch as only 0·1622 gramme was available for SO_3 and H_2O determinations in this analysis the ratio is not bad. One

Digitized by Google

or two attempts to obtain a product with more ThO_2 and less UO_2, by starting with correspondingly different proportions of ThO_2 and U_3O_8, were unsuccessful, perhaps because of the tendency of the thorium sulphate to separate at once in the spongy state and thus to reduce the amount available for slow crystallization with the uranium. The specific gravity of No. II was kindly determined by Mr. L. G. Eakins in alcohol of ·7956 density. It was found to be 4·563 at 24·3° C., which reduced to water at the same temperature as standard becomes 3·63. The material examined contained 1·04 per cent of undissolved U_3O_8 which does not appear in the analysis, and allowing for this a density of 7·3 (Clarke's tables) that of the double sulphate having the given composition is 3·61 at 24·3° C.

The uranium sulphate, of which the analysis is here given, was obtained by decomposing U_3O_8 with dilute sulphuric acid in the manner already mentioned. Its density was not ascertained.

III.

	Analysis.	Molecular ratio.
UO_2	53·99	1·00
SO_3	31·94	2·00
H_2O	14·13	3·94
	100·06	

It appears, as was to be expected, that thorium is capable of replacing uranium in the sulphate of the latter, which holds in combination four molecules of water. That this is a true case of isomorphism is most fully shown by Mr. W. H. Melville in the crystallographical part of this paper, although the habit of the uranium sulphate differs from that of the double salt.

While, as above stated, failure resulted from attempts to lower the ratio between ThO_2 and UO_2 in the green double salt, it was found that the spongy mass, which almost always formed in the tubes when thoriferous uraninite was decomposed with dilute sulphuric acid, contained a very much higher proportion of ThO_2, and that by taking the dioxides in varying proportions double salts of correspondingly different composition could be readily obtained, as shown by the following analyses:

	I.		II.	
	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.
UO_2	34·34	1·00	16·92	1·00
ThO_2	19·84		36·07	
SO_3	31·48	1·95	32·66	2·05
H_2O (diff.)	14·34	3·95	14·35	4·01
	100·00		100·00	

Digitized by Google

Both salts were obtained from a mixture of U_3O_8 and ThO_2. In case of No. II the proportion was such that the UO_2 of the U_3O_8 was to the ThO_2 as 2 to 1. It happened that the tube containing this preparation lay unopened for several weeks after removal from the oven, but during this time there had been no perceptible resolution of the precipitate, which on agitation made a thick emulsion with the acid. Both products were thrown on a Gooch crucible without asbestus felt, quickly washed twice or thrice with hot dilute sulphuric acid and then with alcohol and ether, whereupon they were allowed to dry thoroughly in the air.

There is no reason to doubt the isomorphism of this salt with that formed under similar conditions from thorium alone, but whether these are crystallographically referable to the green crystals before described or form a new case of dimorphism must remain undetermined until the crystallographic features of the former are known. In polarized light the needles of the double salt extinguish apparently parallel to their length.

Such contradictory statements appear in the literature of the subject regarding the composition of thorium sulphate separated from hot acid solutions, some authorities claiming four and a half molecules of water of crystallization and others only four, that it is very satisfactory to have evidence like that furnished by the above analyses to throw light upon the question. The tendency of late years has been to admit a mutual replaceability of ThO_2 and UO_2 in chemical compounds, though no direct proof seems to have been heretofore established,[1] and it was therefore reasonable to suppose that the composition of the thorium sulphate in question should correspond with that of the well known uranous sulphate with four molecules of water. In the light of the above analyses there is no room to doubt the complete isomorphism of the two sulphates, and that Demarcay[2] and Roozeboom[3] were right in accepting the formula $ThO_4(SO_2)_2$, $4H_2O$, derivable from the more or less incomplete analyses of Berzelius, Berlin, and Chydenius, in preference to $ThO_4(SO_2)_2$, $4\frac{1}{2}H_2O$, afforded by the more numerous ones of Delafontaine.[4]

In possible explanation of Delafontaine's high results for water Roozeboom (op. cit., p. 202) very justly remarks that because of its physical character the salt retains much mother liquor, and that if this be not

[1] Since this was written a paper by Rammelsberg, in the Sitzb. k. preuss. Akad. Wiss., vol XXXIV, 1886, which I had overlooked, has been brought to my attention. In it he shows that the uranous sulphate, formerly supposed to contain eight molecules of water of crystallization, contains in reality nine, and that this salt is isomorphous with the corresponding thorium sulphate.

[2] Comptes Rend., 1883, vol. 96, p. 1860.

[3] Zeit. phys. Chem., 1890, vol. 5, p. 198.

[4] Ann. Chem., vol. 131, p. 100. The statement by Kraut, near the foot of page 687 of Gmelin-Kraut's Inorganic Chemistry, vol. II, part I, is manifestly unwarranted. He considers the evidence in favor of the four-molecule H_2O salt as insufficient and thinks the analyses affording this formula were made upon mixtures which might have resulted through absorption of water by the three-molecule H_2O salt. It is strange that individuality should have been accorded to this latter salt by Chydenius and Cleve, which the former obtained by drying over sulphuric acid, after washing with hot water, the precipitate formed by boiling a weakly acid solution of the sulphates. Roozeboom is certainly correct in excluding this three-molecule H_2O salt from the list of thorium sulphates.

Digitized by Google

removed at a temperature above 45° C. the nine-molecule H_2O salt is formed from it on cooling, so that it is almost impossible not to find too much water. Notwithstanding numerous attempts to prepare the salt $ThO_4(SO_2)_2$, $4H_2O$ from hot acid solutions as well as from warm neutral ones, I have never myself succeeded in reducing the water to four molecules, even though the mass of needles was rapidly washed with hot dilute sulphuric acid and then with alcohol and ether, after freeing from mother liquor by powerful suction on a Gooch crucible without asbestus felt, but my faith in the correctness of the formula with $4H_2O$ is not hereby shaken. A further possible cause of high results will appear from the following: The air-dried salt is said by Delafontaine to be thoroughly nonhygroscopic, and for a given temperature and hygrometric condition of the atmosphere it is true that no change in weight does occur; but if the salt is weighed from day to day, or even twice a day, a very marked gain or loss of weight is observed, depending in degree on the amount of change in the atmospheric conditions. In August and September, when hygrometric and thermometric readings were often high and marked and rapid changes were not infrequent, this gain or loss sometimes amounted within twenty-four hours to over half of 1 per cent of the total weight of the salt, and the extreme change during those months reached 1·22 per cent. It is therefore patent that the formula afforded by analysis may materially depend on whether the salt analyzed was weighed when the weather was hot and moist or cold and dry.

It may not be out of place here to call attention to a possible cause of the frequent discrepancies noticed in the statements of different writers in regard to the amounts of water given off by different substances when placed over sulphuric acid in a desiccator. No one would deny that sulphuric acid of maximum concentration is superior as a drying agent to the same acid somewhat, if only slightly, diluted; but it is probably not known to everyone how much may depend on the strength of the acid used. A case in point is the following: A thorium sulphate containing air-dried, 15·22 per cent H_2O, or 4·23 molecules, lost weight over concentrated sulphuric acid in a tightly closed desiccator as shown in column I, and as in column II over acid which had been in use in another desiccator for a considerable length of time and was subsequently found to have a density of 1·66. The cases are not rigidly comparable, perhaps, because of the different times devoted to the experiments, which were not carried on simultaneously, but they serve to illustrate the point.

Digitized by Google

I.—Acid of 1·84 sp. gr.		II.—Acid of 1·66 sp. gr.	
Time.	Per cent.	Time.	Per cent.
Days.		*Days.*	
1	3·80	1	2·87
3	2·78	2	0·40
5	1·37	3	0·06
9	0·22		
18	8·17	5	3·33

This may be considered an extreme case, but it shows plainly the importance of using fresh acid of full strength whenever experiments of this kind are to be made in order that results may be properly comparable.

Similarly it is improbable that a highly hydrated substance which loses much of its water at 100° C. would show as great a loss when dried in an ordinary air bath as in a current of dry air of that temperature.

Another point to be considered when it is desired to find the maximum amount of water that can be removed by any drying agent in a desiccator (which of course as a method is in general inferior to that in which a continuous current of dry air or other gas is passed over the substance) is that if many days are required for its removal—in other words if the substance is slow to part with its moisture—the later weighings should not be made from day to day but at ever-increasing intervals, otherwise a prematurely constant weight or even an increase may be observed. This is due to the fact that whenever the desiccator is opened, which must be twice for each weighing, it, at least in the upper part, becomes filled with moist air, and the substance itself may absorb some moisture before it can be returned to the desiccator; one or more days may then be required to restore the condition of equilibrium which obtained between the vapor tensions of water in the salt and in the air of the desiccator prior to opening the latter. Especially if the acid has become somewhat weakened is it possible for an increase to take place.

Originality is not claimed for the above observations on methods of drying, but it seems as if attention could not be too strongly or too frequently drawn to the points mentioned, which there is reason to fear are not always observed.

II. CRYSTALLOGRAPHIC DISCUSSION, BY W. H. MELVILLE.

The green crystals of sulphate of uranium and of the double sulphate of uranium and thorium described by Mr. Hillebrand are isomorphous and their crystallographic elements are almost identical. The angles between corresponding faces of the two salts differ by less than one degree, while their axial ratios are the same up to the second decimal

Digitized by Google

place. Indeed the axes plotted for the drawing of the crystals of one salt served for the drawing of those of the other.

The two sulphates crystallize in the prismatic (orthorhombic) system. The habits of the two sets of crystals are quite unlike, and by simple inspection no analogy would seem to exist between them, since those of the double sulphate of uranium and thorium have all the appearance of the pyramidal (tetragonal) combination of forms.

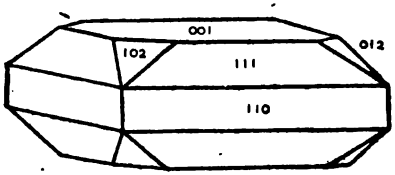


Fig. 1.—Crystalline form of uranium sulphate.

On the goniometer the simple sulphate of uranium presented the most perfect faces, so that very accurate measurements were obtained. On the other hand the similar angles of the double sulphate showed great variations in the readings, often amounting to a difference of 40′ from the mean value. The difficulty of preserving in artificial crystals the same brilliancy of faces after drying which they possess in the mother liquor accounts for the broad bands of these reflect signals. However, after its system of crystallization was identified, the mean of the most perfect and reliable measurements was taken.

The crystals of the double sulphate of uranium and thorium were often twinned, the twinning plane being parallel to (100).[1] Also individuals occurred on the faces (102) and ($10\bar{2}$) which were composed of the face (110) in combination with minute planes of the forms (111) and (012).

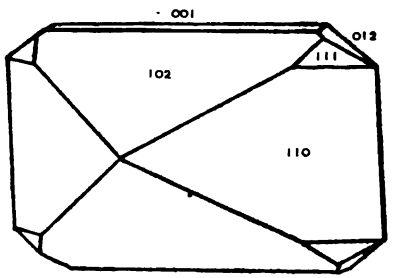


Fig. 2.—Crystalline form of uranium-thorium sulphate.

The forms observed on the crystals of both salts were the same, but unequally developed, as the accompanying figures illustrate, in which

[1] Since the original publication in the Am. Chem. Jour., vol. xiv, p. 1, of the results of the study of the double sulphate it has been found that the twinning is of the nature of interpenetration, and that the composition plane is parallel to (001) on those crystals in my possession.

Digitized by Google

the degree of development in the originals has been preserved. Forms: (001), (010) always a very narrow plane which does not appear in the drawings, (110), (111), (102), (012). Measurements:

(1) Uranium sulphate.	Measured.	Calculated.
	° ′ ″	° ′ ″
001∧111	70 57 00	70 56 30
001∧102	52 13 00	52 10 07
001∧012	33 49 00	33 28 14
111∧111	51 09 00	} fundamental
111∧110	19 08 30	}
110∧1$\bar{1}$0	54 23 00	54 21 00
102∧10$\bar{2}$	75 34 00	75 39 46
Axial ratio: ă : b̆ : ć = 1 : 1·9478 : 2·5755		

(2) Double sulphate of uranium and thorium.	Measured.	Calculated.
	° ′	° ′ ″
001∧102	51 57	51 57 37
001∧012	33 25	33 39 38
111∧1$\bar{1}$1	51 46	} fundamental
111∧110	19 08	}
110∧1$\bar{1}$0	55 14	55 02 24
102∧10$\bar{2}$	76 06	76 04 46
Axial ratio: ă : b̆ : ć = 1 : 1·9194 : 2·5563		

Digitized by Google

POWELLITE—CALCIUM MOLYBDATE: A NEW MINERAL SPECIES.

By W. H. Melville.

Attention has been recently called in mining journals to a locality in the western part of Idaho known as the "Seven Devils" where mining operations for some time past have been actively conducted. "The 'Seven Devils,' about 90 miles due north of Huntington and 15 miles east of Snake river, form a high, broken chain of mountains nearly 9,000 feet above the sea level. The mineral zone is about 1 mile wide by 4 miles in length."[1] The ore is worked for copper and silver, and is mainly the mineral bornite, a sulphide of copper and iron. "The formation on the west of the vein of ore is syenite and quartzite, while on the east wall is a soft white granite. A short distance to the east is a lime contact which extends south for some four miles, and forms a contact with granite. Along this contact some very good chimneys of ore have been discovered."

This bornite carries silver varying in quantity from 12 to 20 ounces to the ton. In one sample of very pure bornite Mr. R. L. Packard found by assay 14 ounces of silver to the ton. A sample from which I had separated for the most part the other mineral constituents gave me 15·65 ounces of silver to the ton. It was this latter fragment of bornite, weighing about 60 grammes, which Mr. Packard picked up from a dump before one of the tunnels in the mining claim called Peacock and which through this gentleman's kindness furnished the material for this paper. The specimen had evidently been exposed to weathering processes and had become friable to such an extent that between the fingers it could be crushed by slight pressure.

There were two associated minerals, one of which was identified by the following partial analysis as a lime-alumina iron garnet. It was light brown, but not crystallized. It fused easily to a black glass.

	Per cent.
Loss on ignition	0·06
SiO_2	38·67
Al_2O_3	10·08
Fe_2O_3	16·00
FeO	0·91
CaO	33·35
MgO	0·77
CuO	trace
	99·84

[1] Quotations from Engineering and Mining Journal, Nov. 22, 1890.

Digitized by Google

Crystallized dark brown garnet is found in considerable abundance throughout this locality. The crystals exhibit the usual combination of rhombic dodecahedron and tetragonal trisoctahedron.

That which proved to be the most important constituent of the specimen, about 1·5 grammes, somewhat resembled scheelite at first sight, but a careful study of its characters excluded that mineral species from consideration. The strong reactions for molybdenum suggested a new species. The mineral was well crystallized and easily detached in almost absolutely pure condition from its friable matrix. Angular measurements were obtained on a number of crystals, from which the crystallographic elements were calculated. The fundamental angle $(111)_{\wedge}(11\bar{1})$ was chosen because of its great accuracy, the signals on the goniometer being perfectly reflected from these planes. Other angles were read oftentimes between reflected signal and reflected light, and again between merely reflected light from the crystal faces. The best crystals were about 0·04 (1^{mm}) long, and others attained the maximum length of 0·10 inch. It was found that the crystals belonged to the pyramidal (tetragonal) system of crystallization, and were closely allied in habit and development to scheelite. In the following table of measurement this analogy is shown.

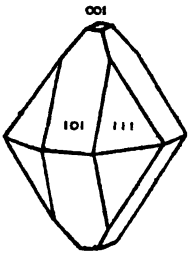


Fig. 3.—Crystalline form of powellite.

$a:c$	Powellite. 1:1·5445		Scheelite.* 1:1·5369
Between normals.	Observed.	Calculated.	
	° ′	° ′	° ′
$111 \wedge 11\bar{1}$	49 12	fundamental.	49 27
$111 \wedge 001$	65 24	65 24	65 16
$111 \wedge 1\bar{1}1$	79 56½	80 1	79 56
$101 \wedge 10\bar{1}$	65 55	65 51	66 6
$101 \wedge 111$	40 1½	40 1	39 58

* Dana's System of Mineralogy, 1883, p. 605.

From this comparison of angles and axial ratio it is evident that sharp and accurate observations must be obtained in order to distinguish by crystallographic means alone between these two species. Many crystals were examined and many trials were necessary before any difference in these angles from those of scheelite could be made out.

The following forms were observed:

(001) $\infty a : \infty a : c$
(111) $a : a : c$
(101) $a : \infty a : c$
(110) $a : a : \infty c$

Small rudimentary planes appear on some crystals at the lower portion of the combination edges (111) (101), thus suggesting hemihedrism

Digitized by Google

as in scheelite. Indeed, the curved surface which often replaces these edges, giving the appearance of fused edges, adds greatly to the evidence in favor of this supposition.

No cleavage planes could be developed by mechanical means, yet occasionally fragments exhibited interrupted planes similar to cleavage surfaces. Hardness less than scheelite, about 3·5. Sp. gr. 4·526, mean of two determinations. Color yellow with a decided green tinge. Luster resinous. Crystals semitransparent. Brittle. The blowpipe characters are those ordinarily given under molybdates and tungstates, although the reactions of molybdenum in this case obscure those of tungsten associated with it. The mineral fuses at about 5 to a gray mass. Decomposed by nitric and hydrochloric acids.

With powellite was associated an olive-green substance which without doubt resulted from the decomposition of calcium molybdate, perhaps by water holding carbonic acid in solution, whereby molybdic ocher was formed.

The following analysis shows the unusual replacement of a part of the molybdic acid by tungstic acid. Rose's method of separating these acids was adopted, and abundant tests proved the purity of the respective products of separation. Molybdenum trisulphide was collected by reverse filtration and aliquot portions were taken for reduction. The molybdenum was weighed first as disulphide, and this weight was checked by reduction to metal in hydrogen gas by strong and long continued ignition. Mercurous tungstate was precipitated, then ignited, and tungstic acid was finally weighed.

Anaylsis of powellite.

	Per cent.	CaO required.
MoO_3	58·58	22·79
WO_3	10·28	2·48
SiO_2	3·25	25·28
CaO	25·55	
MgO	0·16	
Fe_2O_3	1·65	
Al_2O_3	trace	
CuO	trace	
S	undet.	
	99·47	

Calcium molybdate has never before been observed in nature, and although the mineral under discussion contains some calcium tungstate—according to analysis a little less than one molecule to eight molecules of calcium molybdate—yet the molybdate is now established as a species. It fills a gap heretofore existing in the series of isomorphous minerals of which scheelite is the type. If the natural molybdate and tungstate of lime have the same molecular volume as is most

Digitized by Google

probable, then the sp. gr. of pure $CaMoO_4$ should be $200 \div 46{\cdot}9 = 4{\cdot}267$ if the molecular volume, $288 \div 6{\cdot}14 = 46{\cdot}9$, is true for scheelite. By means of the equation for the determination of the sp. gr. of one constituent of a mixture containing two substances of which one is known, the sp. gr. of $CaMoO_4$ is 4·3465 assuming the sp. gr. of $CaWO_4$ to be 6·14 and that of the mixture 4·526 (sp. gr. of powellite). This close agreement in these two calculations of the sp. gr. of $CaMoO_4$ is an interesting and important confirmation of the chemical and physical data which are given above.

When this investigation was nearly completed my attention was called to a recent paper by H. Traube,[1] in which was discussed the influence of certain varying quantities of molybdic acid in scheelite upon the physical constants, namely, sp. gr. and axial ratio. The following scheme is interesting in that it illustrates those variations which different proportions of isomorphous mixtures of $CaWO_4$ and $CaMoO_4$ produce. No mathematical law seems to exist which will express these transitions.

	$CaMoO_4$.	Powellite.	Scheelite.			$CaWO_4$.
			Southwest Africa.	Zinnwald.		
				1	2	
$\%MoO_3$	72	58·58	8·09 7·63	8·23	1·92	0
Sp. gr.	4·267	4·526	5·96	5·88	6·06	6·14
$a:c$	1 : 1·5458	*1 : 1·5445		1 : 1·5349		1 : 1·5315

* Hiortdahl, Zeitsch. Kryst. u. Min., 1887, vol. 12, p. 413.

I take pleasure in naming this new mineral species in honor of Maj. J. W. Powell, Director of the United States Geological Survey.

[1] Neues Jahrbuch., 1890, Beil. Bd. 7, Heft 2.

Digitized by Google

MINERALOGICAL NOTES.

By W. H. Melville.

NATROLITE FROM MAGNET COVE, ARKANSAS.

The specimen of natrolite here described, from Magnet Cove, Arkansas, is associated with feldspar, while in the mass of the natrolite occur crystals of ægirite. From certain cavities crystals were selected which were adapted for measurements. The crystals were often acicular; others were stouter and terminated with brilliant planes. The general mass was compact and exhibited broad and perfect cleavage planes. The fusibility appeared somewhat higher than ordinarily given for natrolite, but thin splinters fused to a colorless bead. The sp. gr. 2·261 was determined.

The long terminated prisms proved to be trimetric and were built up of the forms (010), (100), (110), (111).

The following angles were read:

	° ′	° ′
(110) ∧ (1$\bar{1}$0)	88 51	[1]89
(010) ∧ (110)	[2]44 16	45 30
(111) ∧ (1$\bar{1}\bar{1}$)	36 56	36 40
(111) ∧ ($\bar{1}$11)	37 23½	37 20
(110) ∧ (111)	63 18	63 20

The angle (110) ∧ (1$\bar{1}$0) = 88° 51′ was best obtained from cleavage planes which were found on the crystal, but the mean of all readings on the corresponding crystal planes gave 88° 44′.

Analysis.

	Per cent.		Per cent.
H_2O at 100° C.	0·07	FeO	0·20
H_2O at 250° C.	0·19	CaO	0·13
H_2O at 300°-350° C.	3·42	MgO	0·09
H_2O over gas lamp	5·95	Na_2O	15·40
H_2O over blast	0·00	Total	99·83
SiO_2	47·56		
Al_2O_3	26·82		

[1] The second column of angles was taken from Dana's Mineralogy.

[2] Approximate.

Digitized by Google

TOURMALINE FROM NEVADA COUNTY, CALIFORNIA.

An uncommon form of tourmaline occurs in some localities of Nevada county, Cal. It is radiated and is composed of separable needles which show all the phenomena of hexagonal crystals under polarized light. The needles appear to cleave at right angles to their longer direction, or at all events the cross fracture has all the appearance of cleavage. A mass of these needles possess a dark brown color and silky luster, but singly they are transparent and almost colorless by transmitted light. The mineral fuses very easily to a light brown glass which is nonmagnetic. The specific gravity was found to be 3·065.

In the following analysis the boracic acid is determined by difference, although it was found, according to Marignac's method, to be much less than appears in the summary. The state of the iron was not determined. The analysis is therefore incomplete. Indeed all work upon the mineral ceased after identification.

Analysis.

	Per cent.		
Loss at 100° C	0·02		
Loss over lamp	3·04		
Loss over blast	0·47		
SiO_2	36·40		
Al_2O_3	33·64		
Fe_2O_3	3·13		
CaO	1·51		
MgO	10·01		
K_2O	0·12		
Na_2O	2·49		
F	0·74		
B_2O_3 by difference	8·74	direct.	6·52
	100·31		98·07
Less O	·31		·31
	100·00		97·76

The material analyzed was collected about two miles northwest of Colfax.

SPESSARTITE GARNET FROM LLANO COUNTY, TEXAS.

The following analysis of a yellow-colored mineral from Llano county, Texas, gave very closely the composition of spessartite garnet. It appears that the iron is in part replaced by calcium and magnesium, and hence it is very probable that the iron in this mineral exists in the protoxide state, although it could not be separately determined owing to the admixture of a little black oxide of manganese. The mineral was massive and was associated with quartz, a little magnetite, and black oxide of manganese. The silica was separated before analysis.

Digitized by Google

Analysis.

	Per cent.		Per cent.
Loss at 100° C	0·03	MnO	31·77
Loss on ignition	0·36	CaO	8·48
SiO_2	35·93	BaO	trace.
P_2O_5	none.	MgO	0·69
TiO_2	trace.	Alkalis	0·17
Al_2O_3	18·08		100·11
Fe_2O_3*	4·60		

*FeO corresponding = 4·39.

BISMUTHINITE FROM SINALOA, MEXICO.

A large deposit of bismuthinite occurs in the Rosario mining district, in the state of Sinaloa, Mexico, and it has been recently opened for the production of bismuth as well as for the recovery of silver and gold which the ore carries. An assay of carefully selected material was made, showing the contents of silver and gold to be 65·5 ounces and 0·25 ounce to the ton. This sulphide of bisumuth is associated with considerable chalcopyrite and quartz and occurs in large brilliant blades with the broad cleavage so characteristic of bismuthinite. Its specific gravity is 6·624.

Analysis.

	Per cent.	S. required.
Bi	72·90	16·82
Pb	6·03	0·93
Cu	1·67	0·84
Fe	0·35	0·20
S	18·11	.....
Quartz	0·63	.....
	99·69	18·79

The sulphur comes out too low in the analysis because it was determined in the filtrate from the carbonates precipitated by potassium carbonate, which does not wholly decompose bismuth sulphate.

Digitized by Google

NEW ANALYSES OF ASTROPHYLLITE AND TSCHEFFKINITE.

By L. G. Eakins.

I. ASTROPHYLLITE.

Near the noted cryolite locality at St. Peters dome, in the Pike Peak's region of Colorado, there was found some years ago an unusually fine lot of astrophyllite, and in such a pure condition that it was thought a new analysis would be not without interest, notwithstanding the fact that material from the same region had already been analyzed by König.[1]

This astrophyllite occurs in large, brittle, micaceous blades, golden to brownish yellow in color, and perfectly free from admixed minerals, such as zircon, the only foreign matter being on the ends or sides of the blades which were in contact with the containing rock, so that pure material for analysis was readily obtained. In this analysis the zirconia was separated by a modification of the hydrogen peroxide method and weighed directly, being subsequently identified qualitatively. Fo comparison with this analysis, those made by König and by Bäckström[2] are added to the table below, König's being the one previously referred to, of material from the same region, and Bäckström's of the Eikaholmen mineral.

	Eakins.		König.		Bäckström.	
	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.
Ta_2O_5	0·34	·001	0·80	·002	.....	.....
SiO_2	35·23	·587	34·68	·578	33·02	·550
TiO_2	11·40	·143	13·58	·170	11·11	·139
ZrO_2	1·21	·010	2·20	·018	3·65	·030
Fe_2O_3	3·73	·024	6·56	·041	2·53	·016
Al_2O_3	trace.	.....	0·70	·007	0·98	·009
FeO	29·02	·403	26·10	·362	21·76	·302
MnO	5·52	·078	3·48	·049	11·96	·169
CaO	0·22	·004	.....	.....	1·26	·023
MgO	0·13	·003	0·30	·008	0·92	·023
K_2O	5·42	·058	5·01	·053	5·78	·062
Na_2O	3·63	·059	2·54	·041	2·77	·045
H_2O	4·18	·232	3·54	·197	3·47	·193
			CdO ·42	·006	F 0·97	·051
	100·03		99·91		100·18	

[1] Proc. Am. Phil. Soc. Philad., 1877, vol. 16, p. 509.

[2] Given by Brögger in Groth's Zeitschrift, vol. 16. W. C. Brögger, Die Mineralien der Syenitpegmatitgänge, etc.

Digitized by Google

From a discussion of these analyses of Bäckström and König, Brögger deduces the general formula $R''_4R'_4Ti(SiO_4)_4$ for astrophyllite. It will be seen that my analysis closely confirms this formula, agreeing with it better, in fact, than those from which it was derived. Calculating the small amount of ferric oxide present in with the R'' group, the molecular ratios of my analysis give the following elementary proportions:

$$Si_{567}O_{2389}Ti(Zr)_{153}R''_{536}R'_{234}H_{464}$$

This reduces to

$$Si_4O_{16\cdot3}Ti_{1\cdot04}R''_{3\cdot65}\underbrace{R'_{1\cdot6}H_{3\cdot1}}_{4\cdot7},$$

which is close to $R''_4R'_4Ti(SiO_4)_4$; the excess of the R' group is presumably due to the percentage of water being somewhat too large; this may result from incipient alteration of the mineral, which may also be the cause of the variation in color.

II. TSCHEFFKINITE.

A fragment of this rare mineral was last year sent to the National Museum by Mr. Horace M. Engle, of Roanoke, Virginia. And upon its identification he very kindly presented all at his disposal for the purpose of investigation; in addition to some small fragments there was one large mass, which before breaking weighed over 3½ kilograms, most of it now being in the museum collection. It was found in Bedford county, Virginia, a point considerably farther south than the locality of the material analyzed by Price.[1] The various pieces of this tscheffkinite when found were all more or less rounded nodules, with a superficial brownish yellow ocherous coating, evidently an alteration product, which at some later date may be made the subject of investigation to endeavor to determine the method of alteration. The beginning of this alteration was also seen in the numerous fissure planes developed in breaking up these nodules. Examination of a fresh surface showed a distinctly banded structure of lustrous black and dull black material, the bands varying from mere lines to over 5 millimeters in width. As well as could be these two differently appearing substances were separated and each analyzed by itself; such separation, however, was only approximate, as under a magnifying glass it was seen that each band contained veins of the other. Analysis I is that of the lustrous part and II that of the dull.

Duplicate determinations confirmed these specific gravities, the seemingly more altered one being the higher. The action of acids on the powdered materials shows a marked difference, the lustrous portion being completely decomposed in a few minutes by warm and moderately strong hydrochloric, sulphuric, or nitric acids, while an hour or more was necessary to decompose the dull portion under similar conditions.

[1] R. C. Price, Am. Chem. Journal, Jan., 1888.

Digitized by Google

These analyses show that the two bands are practically identical in composition, the dull being somewhat more hydrated. The molecular ratios seem to lead to no definite or satisfactory formula, a result quite in accordance with the evidence furnished by the microscopical examination of sections. For this purpose chips were taken showing both bands, but as in the case of the chemical analysis, they were seen to be practically the same.

	I.		II.	
	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.
Ta_2O_5	0·08	.....	0·08	.....
SiO_2	20·21	·337	21·49	.358
TiO_2	18·78	·235	18·99	·237
ZrO_2	trace (?)	.....	trace (?)	.....
ThO_2	0·85	·003	0·75	·003
$(Y, Er)_2O_3$	*1·82	·006	†1·64	·005
$(La, Di)_2O_3$	19·72	·059	17·16	·052
Ce_2O_3	20·05	·061	19·08	·058
Al_2O_3	3·60	·035	3·65	·036
Fe_2O_3	1·88	·012	2·89	.018
FeO	6·91	·096	5·92	·082
CaO	4·05	·072	5·24	·094
MgO	0·55	·014	0·48	·012
Na_2O	0·06	·001	0·04	·001
H_2O	0·94	·052	2·06	·114
	99·50		99·47	
Specific gravity	4·33 at 27°		4·38 at 22°.2	

* Molecular weight = 308. † Molecular weight = 312.

I am indebted to Mr. Whitman Cross, of the U. S. Geological Survey, for the following notes on the thin sections:

The sections consist mainly of reddish and yellowish brown transparent amorphous substance, apparently the original material; this is traversed in all directions by cracks, from which there has proceeded a decomposition producing a reddish-brown opaque ocherous matter, which fills the cracks and replaces the original material so that in certain spots there is now merely a network of the two substances. In each section there are two parallel bands of secondary minerals, nothing corresponding to which was detected in the chips before the sections were made. These bands consist chiefly of two colorless minerals, the more abundant occurring in irregular grains closely resembling calcite in strength of refraction and double refraction; the other occurs in rounded grains and is probably sphene. In addition to the two colorless minerals in these bands, there also appear two brownish substances, one of which has distinct prisms, without terminal planes, shows strong pleochroism, and its absorption parallel to the vertical axis is so strong as to make it opaque, while at right angles to this axis it is yellow-brown. More abundant than this prismatic mineral is one occurring in apparent flakes of reddish-brown color; it is doubly refracting, but not strongly pleochroic, and can not be identified with any of the substances already mentioned. Adjacent to these bands, and replacing the amorphous material to varying distances, is still another substance, in general appearance similar to the prismatic mineral, but evidently different as it shows

Digitized by Google

no very marked absorption. This mineral is also strongly pleochroic, varying from yellow-brown to chestnut-brown. All of it in the sections seems to have a uniform crystallographic orientation, the cause of this uniformity not being apparent. Its relations to the amorphous substances are similar to those which I have observed in several instances between crystalline allanite and the amorphous variety.

The microscopical examination having shown this tscheffkinite to be such a mixture, it became desirable to examine others in the same way.

The only one available for this purpose was that analyzed by Price, a specimen of which is in the National Museum collection. This specimen has the same general appearance and banded structure as my own. Chips were taken from it for sections, which Mr. Cross examined and found to be in every respect similar to the other, about the only noticeable difference being in Price's material a somewhat greater development of the opaque ocherous decomposition product of the transparent amorphous substance than in mine, and a lesser development of the colorless minerals.

Taking into consideration the results of this work, and the manifest contradictions of most of the earlier analyses, it seems reasonable to conclude that, unless one of the earlier analyses can be shown to have been made on pure material, the so-called tscheffkinite is not a mineral in any strict construction of the word, but merely a mixture; the structure of the chemically complex body or bodies evidently its basis being a problem to be elucidated in the future when purer material may be found.

Digitized by Google

TWO NEW METEORITES.

By L. G. Eakins.

I. METEORIC IRON FROM PULASKI COUNTY, VIRGINIA.

The material for this analysis was furnished by Mr. G. F. Kunz, in whose possession the original mass, weighing about 30 pounds, now is. This iron calls for no special comment in itself. The specific gravity is 7·95 at 23°.

Analysis.

Fe	93·59
Ni	5·56
Co	0·53
Cu	trace.
P	0·27
S	0·01
Si	trace.
	99·96

II. STONE FROM WASHINGTON COUNTY, KANSAS.

The material for this work was also furnished by Mr. Kunz. A detailed account of its fall has been published by Mr. F. H. Snow, in Science, July 18, 1890. This stone fell on June 25, 1890, and was noted by several observers by the sound it made on falling, the actual fall also being seen by at least one; on striking the earth it buried itself out of sight in a hole about 4 feet deep.

The stone when taken up weighed 184 pounds, and was cracked in two.

In general appearance it is grayish black, with white particles scattered throughout, these being probably a pyroxene. Particles of troilite and of iron were also visible.

The specific gravity of the mass was 3·49 at 21·6°.

As is usual with this class of stones the metallic portion was extracted and analyzed by itself; the portion from which this was taken then being treated with dilute hydrochloric acid, this dissolving troilite and olivine.

The analyzes are as follows:

Digitized by Google

Metallic particles.

Fe	86·76
Ni	12·18
Co	·83
	99·77

Material left after extracting metallic particles.

	Soluble in HCl.			Insoluble in HCl.	
	Analysis.	Less troilite.	Calculated to 100 per cent.	Analysis.	Calculated to 100 per cent.
SiO_2	19·15	19·15	38·50	24·29	53·80
Al_2O_3	.....	.....	.....	1·95	4·32
Cr_2O_3	.....	.....	.....	·64	1·41
FeO	16·15	11·71	23·54	5·41	11·98
NiO	·34	·34	·69	.....	.....
CoO	trace.	trace.	trace.	.....	.....
MnO	·17	·17	·34	trace.	trace.
CaO	·06	·06	·12	1·84	4·08
MgO	18·31	18·31	36·81	10·10	22·37
K_2O	.....	.....	.....	·12	·27
Na_2O	.....	.....	.....	·80	1·77
S	1·97	.....	.....	.....	.....
	55·15	49·74	100·00	45·15	100·00
Less O for S	·99				
	55·16				

It will be seen that in the analysis of the part soluble in hydrochloric acid all the sulphur found has been calculated as troilite. Taking this amount, the metallic particles found, and the relative proportions of the silicates, the approximate composition of the mass is found to be:

Nickel iron	7·7
Troilite	5·0
Silicates soluble in HCl	46·0
Silicates insoluble in HCl	41·5
	100·2

Digitized by Google

ON THE ACTION OF PHOSPHORUS OXYCHLORIDE ON THE ETHERS AND CHLORHYDRINES OF SILICIC ACID.

By H. N. Stokes.

That silica can combine with other acids, forming mixed anhydrides, has long been known, and several such bodies have been described. Friedel and Ladenburg[1] obtained the tetra-acetyl derivative $Si(O.CO.CH_3)_4$ by treating silicon tetrachloride with acetic acid or anhydride. Friedel and Crafts[2] obtained $Si(OC_2H_5)_3O.CO.CH_3$ from ethyl orthosilicate and acetic anhydride. Hautefeuille and Margottet[3] described a crystalline compound, $SiO_2.P_2O_5$, formed by fusing amorphous silica with metaphosphoric acid.

By the action of phosphorus oxychloride on silicic ethers and their chlorine derivatives, I have obtained bodies which consist of phosphoryl chlorides, in which the chlorine is partly replaced by a residue of silicic acid, and which are therefore chlorides of silicophosphoric acids.

Phosphorus oxychloride was caused to react upon *orthosilicic ethyltrichlorhydrine*, $SiCl_3.OC_2H_5$, hoping thereby to obtain the silicon oxychloride described by Friedel and Ladenburg[4] and by Troost and Hautefeuille:[5]

$$3SiCl_3.OC_2H_5+POCl_3=(SiCl_3O)_3PO+3C_2H_5Cl,$$

and

$$2(SiCl_3O)_3PO=3Si_2OCl_6+P_2O_5.$$

The experiment proved that this reaction does not take place.

If the trichlorhydrine be heated in a sealed tube with an excess of phosphorus oxychloride, no reaction is apparent below 175°, the contents remaining perfectly clear. If the temperature be kept at 180–200°, a white amorphous substance is soon formed, which is sufficiently porous to absorb all the liquid products. After two to three hours' heating the tube is opened, when ethyl chloride escapes in large quantities. On placing the tube in an air bath, heated at about 150°, and connecting it with a condenser, a large amount of liquid may be collected. The solid remaining in the tube may then be freed from excess of phosphorus oxychloride by passing a current of dry air over it by means of a capillary.

[1] Ann. Chem. (Liebig), vol. 146, p. 174.
[2] Ann. chim. phys. [4], vol. 9, p. 47.
[3] Compt. rend., vol. 96, p. 1052.
[4] Ann. Chem. (Liebig), vol. 147, p. 355.
[5] Ann. chim. phys. [5], vol. 7, p. 465.

Digitized by Google

The liquid, on fractioning, is readily separated into phosphorus oxychloride (boiling at 110°) and silicon tetrachloride (boiling at 57°–61°), though much of the latter is lost, being carried off by the ethyl chloride, which is abundantly held in solution. The product obtained after six distillations was analyzed.

	Calculated for $SiCl_4$.	Found.
Si	16·52	16·24

The view with regard to its nature was confirmed by converting it into ethyl orthosilicate (boiling at 165·5°). As the liquid passed over entirely below 112°, no silicon oxychloride was formed, and no substances other than those mentioned could be detected. Analyses of the solid substance gave—

	Calculated for $SiP_2O_6Cl_2$.	Found.	
		I.	II.
Si	10·92	10·17	10·06
P	24·15	25·16	25·11
Cl	27·59	27·33	.....

The agreement is only approximate, as the substance could not be purified in any way; and on heating too long or at too high a temperature, when drying, phosphorus oxychloride is slowly given off. It is possibly a mixture of substances, in the formation of which the one supposed represents one stage. If heated above 200° phosphorus oxychloride is given off, and at red heat, phosphorus pentoxide; and the residue, left at a white heat, consists of amorphous silica imbedded in a vitreous substance, probably the compound $SiO_2.P_2O_5$ of Hautefeuille and Margottet. The loss on heating corresponds to the equation—

$$6SiP_2O_6Cl_2 = 3SiO_2 + 3(SiO_2.P_2O_5) + 4POCl_3 + P_2O_5.$$

	Calculated.	Found.
Loss	49·01	51·86

The formation of the substance, which, for reasons given below, may be designated as *silico-pyrophosphoryl chloride*, is most simply expressed by the equation—

$$4SiCl_3(OC_2H_5) + 2POCl_3 = 3SiCl_4 + SiP_2O_6Cl_2 + 4C_2H_5Cl.$$

Silico-pyrophosphoryl chloride is a very bulky substance, resembling the lightest form of amorphous silica. It may be obtained perfectly colorless, but is usually more or less colored by organic matter, formed

by secondary reactions, when heated too high. It is extremely hygroscopic, and gives off hydrochloric acid instantly when exposed to moist air. It is readily soluble in absolute alcohol, a proof that it contains no free silica. The alcoholic solution, which probably contains an ether of silico-phosphoric acid, may oe evaporated nearly to dryness or heated any length of time at 150° without decomposition. On heating at 225° it soon deposits transparent, gelatinous silica. The solution in alcohol is attended with considerable rise of temperature. The substance is insoluble in ether. If cold water be poured on the fine powder it readily dissolves, with the exception of a few flakes of silica; but if first moistened, or if in lumps, most of the silica remains undissolved. The best way to get a clear aqueous solution is to dissolve in a little alcohol and then to dilute with water. The reaction with water alone is somewhat violent. The aqueous solution may be kept a long time—indeed, may be strongly concentrated on the water bath—but on evaporation *to dryness* a vitreous mass is left, from which water extracts phosphoric acid only.

All attempts to prepare salts of silico-phosphoric acid have failed. Ammonium carbonate precipitates gelatinous silica. If the cold aqueous solution, prepared as described above, be acidified with nitric acid, excess of silver nitrate added, and filtered from silver chloride, a clear solution is obtained. If to this be added, drop by drop, dilute ammonia, a white precipitate is formed, which at a certain point changes to yellow. The analysis of the white substance (dried at 100°) gave—

	Calculated for $Ag_4P_2O_7$.	Found.
Ag	71·17	71·25

The yellow precipitate proved to be merely silver ortho-phosphate.[1] The filtrate from the silver salts gives an abundant precipitate of silicic acid when warmed with ammonia. The magnesia precipitate also shows the characteristic reaction of magnesium pyro-phosphate, dissolving in acetic acid when precipitated in the cold, and being reprecipitated from this solution on boiling.

The substance is therefore a derivative of pyro-phosphoric acid, and the formation of some ortho-phosphoric acid may be explained by the decomposition of the former, pyro-phosphoryl chloride dissolving in water with formation of ortho-phosphoric acid.[2]

Heated with phosphorus pentachloride at 100°, silico-pyrophosphoryl

[1] The reaction described above affords a convenient method for separating, at least approximately, ortho- from pyro-phosphoric acid. A solution of the acids—or their soluble salts—is acidified in the cold with nitric acid and silver nitrate added in excess. On adding dilute ammonia, drop by drop, all the pyro-phosphoric acid is precipitated before any of the ortho-phosphoric acid comes down. At this point a single drop of ammonia gives a yellow tinge to the precipitate, which a drop of dilute nitric acid causes to disappear. If the liquid be now filtered, all the pyro-phosphoric acid will be in the precipitate and all the ortho-phosphoric acid in the filtrate. The reaction is so sharp that it might possibly be used to separate the acids quantitatively.

[2] Michaelis: Ber. d. deutsch. chem. Ges., vol. 4, p. 767.

Digitized by Google

chloride is readily and quantitatively converted into silicon tetrachloride and phosphorus oxychloride:

$$SiP_2O_6Cl_2 + 4PCl_5 = SiCl_4 + 6POCl_3.$$

The tetrachloride was isolated, and expectations with regard to its nature were confirmed on converting it into the ether (b. p., 165·5°). No silicon oxychloride could be obtained. If heated with an insufficient amount of phosphorus pentachloride, the excess remains apparently unchanged.

The conversion of a derivative of silicic acid into silicon tetrachloride at so low a temperature has not been hitherto observed. R. Weber[1] obtained the tetrachloride and phosphorus oxychloride by passing the vapor of phosphorus pentachloride over silica at a red heat. As the pentachloride is completely dissociated at 300° into trichloride and chlorine, the reaction is due to the action of chlorine, combined with the reducing action of the trichloride—

$$SiO_2 + 2PCl_3 + 2Cl_2 = SiCl_4 + 2POCl_3—$$

which is analogous to the old method of preparing the tetrachloride—

$$SiO_2 + 2C + 2Cl_2 = SiCl_4 + 2CO.$$

As I have convinced myself, phosphorus pentachloride does not act on amorphous silica (dried at 100°) even at 250°, further than to dehydrate it.

The action of a smaller quantity of phosphorus oxychloride on the trichlorhydrine is similar. Three-molecule trichlorhydrine and one-molecule oxychloride, heated at 180°, gave ethyl chloride, silicon tetrachloride, and a solid product completely soluble in alcohol and water, the composition of which differed, however, from that of the substance above described. (Found: Si, 15·25; P, 22·30; Cl, 14·13.)

The action of an excess of phosphorus oxychloride on the chlorhydrines $SiCl_2(OC_2H_5)_2$ and $SiCl(OC_2H_5)_3$ is essentially similar. At 180–200° a solid substance is formed, with much ethyl chloride and silicon tetrachloride. The amount of the tetrachloride is directly, and that of the solid inversely, proportional to the amount of chlorine in the chlorhydrine. In each case the tetrachloride was isolated in a state of approximate purity and converted into the ortho-ether, boiling at 165·5°. No other volatile substances could be detected. The solid body was completely soluble in alcohol and, in brief, showed all the properties above described as belonging to silico-pyrophosphoryl chloride. The analysis of the product from $SiCl_2(OC_2H_5)_2$ gave—

	Calculated for $SiP_2O_6Cl_2$.	Found.	
		I.	II.
Si	10·92	11·68	11·80
P	24·15	24·53	24·91

[1] Ann. der Phys., Pogg., vol. 112, p. 619.

Digitized by Google

The product from $SiCl(OC_2H_5)_3$ gave—

	Calculated for $SiP_2O_6Cl_2$.	Found.
Si	10·92	10·15
P	24·15	24·54
Cl	27·59	24·73

The results, as before, are only approximate; but, it must be remembered, the body loses phosphorus oxychloride slowly on heating, and only the crude product could be analyzed. The reactions in these cases are:

$$4SiCl_2(OC_2H_5)_2 + 4POCl_3 = 2SiCl_4 + 2SiP_2O_6Cl_2 + 8C_2H_5Cl,$$
$$4SiCl(OC_2H_5)_3 + 6POCl_3 = SiCl_4 + 3SiP_2O_6Cl_2 + 12C_2H_5Cl.$$

Orthosilicic ether, $Si(OC_2H_5)_4$, was heated with excess of phosphorus oxychloride for two hours at 180°–200°. The tubes contained a solid substance and ethyl chloride. On distilling off the excess of oxychloride and decomposing it with water only a trace of silica was left after evaporation, showing that practically no volatile silicon compound was formed. The solid, the properties of which were in every respect identical with those of the body above described, gave on analysis—

	Calculated for $SiP_2O_6Cl_2$.	Found.		
		I.	II.	III.
Si	10·92	9·22	10·05	10·21
P	24·15	25·52	25·63	25·84
Cl	27·59	29·66	29·90	.....

The reaction is, therefore, represented by the equation—

$$Si(OC_2H_5)_4 + 2POCl_3 = SiP_2O_6Cl_2 + 4C_2H_5Cl.$$

The constitution of the silico-phosphoryl chloride is possibly very complex. The simplest constitutional formula, deduced from the last equation, would be

$$Si\begin{cases} O \\ O \end{cases} > POCl \quad ;$$
$$\quad\quad\quad

or a polymer containing the group —O.PO.O.PO.O—, which makes it a derivative of metasilicic acid. The cause of the formation of silicon tetrachloride from the chlorhydrines is not clear. It is obviously not due to a direct replacement of ethoxyl by chlorine, for then it should be obtained in the same amount from each chlordydrine, or from the ether; whereas the latter does not give it, and the amount obtained from the former is proportional to the amount of chlorine they already contain. Besides, no phosphoric ethers are formed. Nor does the supposition explain the formation of silico-pyrophosphoryl chloride in quantities inversely as the amount of chlorine. A possible explanation is the following: The chlorhydrines[1] are formed by heating mixtures of orthosilicic ether with silicon tetrachloride, or of either of these with other chlorhydrines, that one being formed in largest amount which corresponds in composition to the mean composition of the mixture; for example—

$$3Si(OC_2H_5)_4 + SiCl_4 = SiCl(OC_2H_5)_3.$$
$$2SiCl_3(OC_2H_5) + Si(OC_2H_5)_4 = 3SiCl_2(OC_2H_5)_2.$$

These reactions take place below 200°; partial dissociation occurring, the products reuniting to form that body which tends to give the liquid a homogeneous composition. Doubtless the reverse process takes place at the same time; for example—

$$4SiCl(OC_2H_5)_3 = 3Si(OC_2H_5)_4 + SiCl_4;$$

and if phosphorus oxychloride be present—which, as just shown, destroys the ether—this can go on until all the chlorhydrine has been converted into ether and tetrachloride. This explanation is simple enough, but, as shown by the action of phosphorus oxychloride on *disilicic* chlorhydrines, the actual process is possibly more complicated.

By heating a mixture of trichlorhydrine, phosphorus and iodine, a solid of similar properties was obtained, and silicon tetrachloride was formed. The reaction was not followed further.

ACTION OF PHOSPHORUS OXYCHLORIDE ON DERIVATIVES OF DISILICIC ACID.

Hexethyl disilicate,[2]

$$O<\begin{matrix}Si(OC_2H_5)_3\\Si(OC_2H_5)_3\end{matrix},$$

was heated with an excess of phosphorus oxychloride in sealed tubes at 180–200° for two or three hours. The tubes contained a white solid, outwardly resembling silico-pyrophosphoryl chloride and much ethyl chloride. No volatile silicon compound was formed. The solid resembled in its general properties the one described. It was completely soluble in alcohol, and therefore contained no free silica. The solution

[1] Friedel and Crafts: Ann. chim. phys. [4], vol. 9, pp. 11, 14, 15.
[2] Ibid, p. 24.

Digitized by Google

gave the reactions of pyro-phosphoric acid. It differed markedly in composition from the orthosilicic derivative, the analysis giving—

	Calculated for $SiP_2O_5Cl_2$.	Found.
Si	10·92	17·02
P	24·15	23·91
Cl	27·59	21·04

This corresponds to no probable formula, but contains 4 atoms Si to 5 atoms P, instead of 1 atom Si to 2 atoms P. Phosphorus pentachloride converts it readily (at 100°) into silicon tetrachloride and phosphorus oxychloride. No silicon oxychloride is formed, the product passing over entirely below 112°. The tetrachloride was isolated and converted into the tetrethyl ether (boiling at 165.5°).

The ease with which the ortho-chlorhydrines give, with phosphorus oxychloride, silicon tetrachloride, led to an analogous experiment with the *disilicic chlorhydrines*, in the hope that in this way silicon oxychloride might be obtained. On the above hypothesis, we should have, in the presence of phosphorus oxychloride, the following reaction:

$$6O<\begin{matrix}SiCl_3\\SiCl_2(OC_2H_5)\end{matrix}=5O<\begin{matrix}SiCl_3\\SiCl_3\end{matrix}+O<\begin{matrix}Si(OC_2H_5)_3\\Si(OC_2H_5)_3\end{matrix};$$

and analogous reactions with the other chlorhydrines.

The disilicic chlorhydrines, which have not hitherto been prepared, are formed by heating disilicic ether with an excess of silicon tetrachloride for several hours at 200°. A gradual exchange of ethoxyl and chlorine occurs, disilicic chlorhydrines and ortho-silicic trichlorhydrine being formed. After distilling off the latter, the residue is again heated with silicon tetrachloride, whereby the conversion is carried further. In this way a mixture of disilcic chlorhydrines was obtained, which, after freeing from all ortho-silicic compounds by repeated distillation, boiled at 170–220°. A chlorine determination showed that it contained the equivalent of 65 per cent Si_2OCl_6. No attempt was made to isolate any of these chlorhydrines, as no less than eight are theoretically possible, and it was presumed that they would all act in the same way toward phosphorus oxychloride. The mixture was heated with excess of phosphorus oxychloride (based on the amount of chlorine shown by analysis) for two and a half hours at 180–200°; after which no further action was observed. The appearance of the product was the same as in previous experiments. The liquid product was distilled off and fractioned. It was found to consist of an excess of phosphorus oxychloride, of *silicon tetrachloride*, which was recognized through conversion into the ether, and ethyl chloride. The liquid boiled entirely below 112°, and therefore none of the expected silicon oxychloride was formed. The solid product was markedly different from those before obtained. It

Digitized by Google

was only partly soluble in alcohol, and on boiling out with the solvent a large residue of *silica* was left. Besides a soluble silico-phosphoryl chloride and ethyl chloride the only products were silicon tetrachloride and silica. If the oxychloride be formed at all, it is at once decomposed in the presence of phophorus oxychloride—

$$2Si_2OCl_6 = 3SiCl_4 + SiO_2$$

Whether this actually occurs is questionable, as the oxychloride and all the other substances concerned are, by themselves, stable at a much higher temperature than that employed. I am unable to give any satisfactory explanation of the reaction.

Amorphous silica, prepared from water-glass and dried at 100°, gives with phosphorus oxychloride a small amount of silico-phosphoryl chloride, soluble in alcohol: 3·5 per cent of the silica was converted into this compound.

The silicon tetrachloride used as the starting-material of these experiments was made by the admirable method of Gattermann.[1] For preparing the silicon mixture I used, instead of test tubes, sheet-iron crucibles of about 200^{cc} capacity. These are nearly filled with an intimate mixture of three parts quartz powder and one part magnesium powder, tightly pressed down. On heating over a blast lamp, the reaction starts in a few seconds, and is indicated by the whole crucible suddenly becoming red-hot. During the reaction the lid must be held down firmly. I prefer to extract the magnesia from this product before using it, as less care has to be used in regard to temperature when passing chlorine over it. By using ice alone, to condense the chloride, nearly the theoretical yield is obtained; the crude product loses about 15 per cent in the process of purification.

The *orthochlorhydrines* were prepared essentially according to the method of Friedel and Crafts.[2] Any mixture may be used which coincides in composition with that of the chlorhydrine desired. The yield is never theoretical, no matter how long the heating may be continued. The yields of pure substance, obtained after six distillations, were as follows: Monochlorhydrine, 65 per cent; dichlorhydrine, 40 per cent; trichlorhydrine, 47 per cent. More can, of course, be obtained by uniting and heating the residues.

Friedel and Crafts[3] obtained the disilicic ether by adding to silicon tetrachloride, drop by drop, alcohol containing the calculated amount of water. They claim that the yield is nearly theoretical. I am not able to confirm this statement. By following their directions exactly, I obtained a mixture of ortho- and disilicic ethers, with ethers of much higher boiling points. After repeated fractioning, only 33 per cent of the theoretical yield of disilicic ether was obtained, and the amount of

[1] Ber. d. deutsch. chem. Ges. vol. 22, pp. 186-188.
[2] Loc. cit.
[3] Ann. chim. phys. [4] vol. 9, p. 26.

Digitized by Google

ortho-ether was much greater. This is due to the fact that the added water acts on the disilicic ether already formed, giving more complex bodies, so that there is an excess of tetrachloride, which is converted into ortho-ether.

The essential results of these experiments may be summed up as follows:

Phosphorus oxychloride acts on orthosilicic ether and its chlorine derivatives according to the following equations:

I. $4Si(OC_2H_5)_4 + 8POCl_3 = 4SiP_2O_6Cl_2 + 16C_2H_5Cl.$

II. $4SiCl(OC_2H_5)_3 + 6POCl_3 = SiCl_4 + 3SiP_2O_6Cl_2 + 12C_2H_5Cl.$

III. $4SiCl_2(OC_2H_5)_2 + 4POCl_3 = 2SiCl_4 + 2SiP_2O_6Cl_2 + 8C_2H_5Cl.$

IV. $4SiCl_3(OC_2H_5) + 2POCl_3 = 3SiCl_4 + SiP_2O_6Cl_2 + 4C_2H_5Cl.$

The body $SiP_2O_6Cl_2$ is the chloride of a silico-pyrophosphoric acid, is decomposed by water into silica and pyrophosphoric acid and is easily converted by phosphorus pentachloride into silicon tetrachloride and phosphorus oxychloride.

The ether of disilicic acid acts similarly, giving a silico-phosphoryl chloride of different composition but analogous properties.

The chlorhydrines of disilicic acid do not give with phosphorus oxychloride, as might be inferred, a silico-phosphoryl chloride and silicon oxychloride, but a mixture of the first with free silica and silicon tetrachloride.

Phosphorus trichloride also acts on orthosilicic ether at 200°, giving a white solid, and liquid products, which will be further studied.

Digitized by Google

ON THE COLLOIDAL SULPHIDES OF GOLD.

By E. A. Schneider.

The credit of having definitely established the proportions in which gold and sulphur combine is due to L. Hoffmann and G. Krüss.[1] They found, as a result of many elaborate experiments, that gold can form with sulphur only aurous sulphide Au_2S and auroauric sulphide Au_2S_2, but not auric sulphide Au_2S_3. It must be observed, however, that lately Antony and Lucchesi[2] have stated that they succeeded in preparing auric sulphide by passing dry hydrogen sulphide over lithium aurochloride.

While studying both the sulphides, which were prepared in a pure state by Krüss, I repeatedly noticed their tendency to form colloidal solutions. I have found in chemical literature some suggestions bearing on this behavior, but no special investigation upon the subject has been recorded. Consequently it seemed desirable to look into the matter.

COLLOIDAL AUROUS SULPHIDE.

Hoffmann and Krüss state that freshly precipitated aurous sulphide forms with water a clear brown solution, without, however, laying any stress on its colloidal nature. Although some of the properties of the solution mentioned by Hoffmann and Krüss, for instance, coagulation by hydrochloric acid and by neutral salts (sodium chloride, potassium chloride), indicate clearly its colloidal character. I have, nevertheless, made an experiment to prove it directly. The brown, clear solution was placed in a dialyser and after the lapse of several days the liquid in the outer jar did not contain a trace of any gold compound. Consequently the aurous sulphide solution is colloidal, and to compare it with sodium sulphide, as Hoffmann and Krüss have done, in order to characterize the position of gold in the periodic system, is not admissible, particularly as it is well known that the sulphides of the heavy metals in general can form colloidal solutions. This subject Spring and Boeck[3] and later Winssinger[4] have investigated. In order to prepare colloidal aurous sulphide in sufficient quantity the directions of Hoffmann and Krüss should mainly be followed, but with the following changes:

[1] Ber. d. deutschen chem. Gesell., vol. 20, pp. 2369 and 2704.
[2] Gazzetta chimica italiana, vol. 20, pp. 601–607.
[3] Bull. de la société chimique, vol. 48, p. 165.
[4] Ibid., vol. 49, p. 452.

Digitized by Google

Aurous cyanide isolated from potassium aurocyanide by means of hydrochloric acid is dissolved in the least possible quantity of potassium cyanide; the solution is then saturated with sulphuretted hydrogen. Hydrochloric acid is now added and the liquid gently warmed until it becomes distinctly brown and cloudy, but the heating should be discontinued as soon as a heavy precipitate begins to form. This solution is next subjected to a prolonged dialysis. In the dialyser remains a dark brown colloidal solution of aurous sulphide, which can be separated by decantation and filtration from solid aurous sulphide, which latter is usually present in considerable quantities.

The strongest solution obtained by this method contained 1·740 grammes aurous sulphide in the liter. An attempt was made to concentrate this liquid in vacuo to half of its bulk. A small quantity, however, of aurous sulphide separated out when this degree of concentration was reached.

When a solution of aurous sulphide is heated to a temperature of 200–230° gold separates out and simultaneously sulphuric acid is formed. On freezing and subsequent thawing aurous sulphide is deposited in solid form. The same behavior has been observed in the case of many other colloidal solutions.[1] It appeared to be of some interest to ascertain whether colloidal aurous sulphide possesses the property to undergo mutual decompositions similar to those of sulphuretted hydrogen and of the soluble sulphides of the alkalies and alkaline earth metals; and particularly whether it would react with other colloidal solutions, such as colloidal ferric hydrate, according to the following equations:

$$2Fe(OH)_3 + 3Au_2S = Fe_2S_3 + 3Au_2O^* + 3H_2O$$
$$2Fe(OH)_3 + 3Au_2S = 2FeS + S + 3Au_2O + 3H_2O$$

Some time ago Wright[2] studied the action of sulphuretted hydrogen on ordinary ferric hydrate. I find that colloidal ferric hydrate behaves in the same way. If sulphuretted hydrogen is conducted into a solution of colloidal ferric hydrate at ordinary temperatures iron sulphide immediately separates out. The reaction proceeds probably according to the equations—

$$2Fe(OH)_3 + 3H_2S = Fe_2S_3 + 6H_2O$$
$$2Fe(OH)_3 + 3H_2S = 2FeS + S + 6H_2O$$

which Wright has demonstrated to be probable in the case of the ordinary compound. If solutions of colloidal ferric hydrate and colloidal aurous sulphide are mixed no reaction takes place either at ordinary or at higher temperatures. This fact confirms the hypothesis[3] that in

[1] Zeitschrift f. phys. Chem., vol. 4, p. 486.

[2] Jour. Chem. Soc., 1883, vol. 43, p. 156.

[3] C. Barus and E. A. Schneider: On the nature of colloidal solutions. Zeitschrift f. phys. Chem., vol. 8, p. 278.

* The soluble aurous oxide has been described by Krüss; Ann. Chem. Pharm., vol. 237, p. 231.

Digitized by Google

colloidal solutions extremely small solid particles are held in suspension, for solid substances do not react among themselves, excepting possibly when very high pressure is used.

COLLOIDAL AUROAURIC SULPHIDE.

Weak solutions of colloidal auroauric sulphide have been already prepared by Winssinger.[1] Comparatively concentrated solutions of auroauric sulphide may be obtained easily and in large quantity when the freshly precipitated compound is boiled with potassium cyanide or potassium polysulphide until about half of the gold salt has gone into solution. The undissolved sulphide is rinsed now with water in a dialyser and subjected to dialysis. After removal of all the crystalloids there remains in the dialyser a dark brown liquid, together with some solid auroauric sulphide, which can be easily separated by decantation and filtration.

The yield is equally good whether potassium cyanide or potassium polysulphide is used. In the second case, however, it seems to be more difficult to remove the crystalloids, even by protracted dialysis.

The colloidal auroauric sulphide solutions are perfectly transparent to both transmitted and reflected light (the latter is not always the case with colloidal solutions).

When the solution is frozen it behaves like the solution of aurous sulphide and most of the other colloids. It undergoes no change when heated to 240° in a sealed tube.

The strongest solution which I was able to obtain, according to the above described method, contained 0·8 gramme auroauric sulphide in the liter. Its color is dark brown and a layer of about 2 centimeters thickness is almost opaque.

In order to ascertain whether the auroauric sulphide had undergone change on dissolving, a liquid containing the compound in colloidal condition was coagulated.

The precipitated sulphide was reddish brown when moist; black when dried. The analysis gave data which corresponded well with the formula Au_2S_2.

Colloidal solutions of *aurous* sulphide can be obtained by treating aurous sulphide with potassium polysulphide, but the yield is much smaller than in the case of auroauric sulphide.

That colloidal solutions are formed by prolonged washing with water of a precipitate which has been already acted on by a solvent has been observed several times. Wright[2] states that ferrous sulphide changes to the colloidal condition if washed with water after previously having been boiled with enough potassium cyanide to effect partial solution. I have repeated the experiment and can fully confirm this statement.

[1] Bull. de la société chimique, vol. 49, p. 452.
[2] Jour. Chem. Soc., 1883, vol. 43, p. 163.

Digitized by Google

Without knowing of Wright's experiments I found several years ago that ordinary ferric hydrate may be converted into its colloidal form by a similar process.[1]

Freshly precipitated ferric hydrate is easily dissolved by a neutral solution of aluminum chloride. Now, if an excess of ferric hydrate is present which does not further dissolve, and if the same is placed on a filter and washed with water until all salts present are removed it goes into a solution which seems to be in its properties almost identical with ordinary dialysed ferric hydrate.

The following explanation can be given of this behavior: If a solvent acts on a finely divided precipitate, single molecules throughout the whole mass of the latter go into solution. Thus the large aggregates of molecules are broken up into smaller ones. These aggregates of molecules may become, under certain conditions, so small that they remain permanently suspended in the liquid and form a so-called "colloidal" solution. It must be added, however, that this happens only in certain cases and with certain substances. If, for instance, silver sulphide is treated exactly in the same way as ferrous sulphide or auroauric sulphide with potassium cyanide and then washed with water no trace of a colloidal solution is formed.

An unsuccessful experiment, which was made with the intention of obtaining colloidal auroauric sulphide by another method, may be mentioned, as it gave rise to an interesting observation. If sulphureted hydrogen is conducted at ordinary temperatures into a solution of auric chloride, very little precipitate is formed as long as undecomposed chloride is present; the color of the solution becomes at the same time dark brown; thin layers of the liquid remain still transparent. This behavior seemed to indicate that at first only colloidal auroauric sulphide is formed. In order to confirm this assumption by experiment a solution of auric chloride was incompletely precipitated by sulphureted hydrogen and then placed in a dialyser. After the lapse of a few hours the unchanged chloride of gold was diffused; in the dialyser, however, remained finely divided gold instead of colloidal auroauric sulphide as had been expected.

It appears that the gold chloride had acted on the auroauric sulphide according to the following equation:

$$Au_2S_2 + (AuCl_3)_4 + 8H_2O = Au_6 + 2H_2SO_4 + 12HCl.$$

And, indeed, if a mixture of the solutions of colloidal auroauric sulphide and gold chloride is gently heated gold immediately separates out. The following quantitative experiment definitely confirms this view. 1·4140 grammes auroauric sulphide (one molecule Au_2S_2) were heated on the water bath with four molecules auric chloride, corresponding to 2·8280 grammes gold. After the lapse of four hours the liquid had become entirely colorless and the brownish black color of

[1] Ann. Chem. Pharm., vol. 257, p. 374.

Digitized by Google

auroauric sulphide had changed entirely to the yellowish brown of metallic finely divided gold. The gold which had thus separated out was carefully washed, dried, digested with carbon bisulphide for some time and ultimately dried at a temperature of 110°. Its weight after this treatment amounted to 4·8708 grammes—on heating and calcining the same a sulphur flame was noted, and a loss of 0·0327 grammes or 0·77 per cent was found; consequently found 4·2381 grammes gold, instead of 4·2420 grammes..

The presence of sulphuric acid as required by the above equation was only qualitatively proved. The presence of a small quantity of sulphur in the gold can be explained by the fact that the auroauric sulphide used was not freed originally from the sulphur which is always formed when gold chloride solution is precipitated by sulphureted hydrogen. Consequently it was possible for the metal to be contaminated with traces of sulphur, which are removed only with great difficulty by carbon bisulphide.

By a second, but not strictly quantitative experiment it was shown that gold chloride reacts with auroauric sulphide in the above described manner even at ordinary temperatures, but the reaction proceeds more slowly. The reduction of boiling solutions of auric chloride by sulphureted hydrogen, which has been already observed by Levol,[1] can be explained by the above reaction.

Finally, colloidal auroauric sulphide was prepared by prolonged treatment of freshly precipitated auroauric sulphide with sulphureted hydrogen water. Freshly precipitated auroauric sulphide was suspended in a few hundred cubic centimeters of water and placed in a dialyser. Sulphureted hydrogen was conducted into the latter for a week, and the water in the outer jar was frequently renewed. After the lapse of this time a light brownish yellow solution had formed in the dialyser. This solution contained 0·023 gramme auroauric sulphide per liter.

It is evident that more concentrated solutions could be obtained if the treatment with sulphureted hydrogen were continued for a longer period. If, however, we compare this method with the preceding it appears long and tedious. Some of the facts mentioned may possibly throw light on certain chemico-geological problems.

It appears probable—

(1) That the separation of free gold in the upper strata of the earth's crust may have been effected by the action of sulphureted hydrogen on chloride of gold;[2] for the constant associate of gold, pyrites, owes its formation, as Doelter[3] has shown in his investigation on that subject, to the action of sulphureted hydrogen water on the various oxides of iron at temperatures below 100°.

[1] Annal. Chim. Phys. (3), vol. 30, p. 356.

[2] The original formation of gold chloride in the earth-crust can be explained by the action of chlorine on gold at a considerable depth.

[3] Zeitschrift f. Kryst. und Min., vol. 11, p. 30.

Digitized by Google

(2) That the formation of gold could have taken place at no very great depth, for we have seen that already at much lower temperatures auric chloride effects the separation of gold from auroauric sulphide solutions.

(3) That the formation of pyrites has taken place in strata nearer the surface than those in which the formation of gold took place, for it is necessary to assume that the mineral acids which are formed, when gold is separated out by sulphureted hydrogen from gold chloride solution, had to be first neutralized by the bases of strata of considerable thickness in order to make possible the formation of pyrites by the action of sulphureted hydrogen on ferric oxide.

In connection with this investigation I have tried the action of high pressures on some colloidal solutions.

A colloidal solution of ferric hydrate (0·64 per cent F_2O_3) was subjected at temperatures of 17° and of 100° to a pressure of 1,700 atmospheres. No visible action was observed. A colloidal solution of silicic acid (1·22 per cent) also remained at 17° and at 100° under the same pressure entirely unchanged.

Digitized by Google

MISCELLANEOUS ANALYSES.

THREE MINERALS FROM COLORADO.

[Collected by Whitman Cross, analyzed by L. G. Eakins.]

A. Heulandite, from Anthracite creek, Gunnison county.
B. Diaspore, from Mount Robinson, Custer county.
C. Alunite, from Knickerbocker hill, Custer county.

	Heulandite.	Diaspore.	Alunite.
SiO_2	57·38	.....	2·82
Al_2O_3	17·18	83·97	38.91
Fe_2O_3	trace	.....	.....
CaO	8·07	.....	·35
MgO	.....	.....	trace
K_2O	·40	.....	4·03
Na_2O	·82	.....	4·32
H_2O	16·27	15·43	13·03
SO_3	.....	.....	35·91
	100·12	99·40	99·37
Sp. gr.	2·24, 21°		

YELLOW SMITHSONITE FROM ARKANSAS.

[Collected in Marion county by W. P. Jenney, and analyzed by H. N. Stokes.]

Bright golden yellow in color. Takes a fine polish. Known locally as "turkey-fat ore."

SiO_2	·06
CO_2	34·68
Cu	trace
CdS	·25
CdO	·63
ZnO	64·12
FeO	·14
CaO	·38
	100·26

Digitized by Google

ROCKS AND CLAYS FROM THE ZINC REGION OF MISSOURI AND KANSAS.

[Collected by W. P. Jenney.]

First. Two dolomites from the Oswego land, Joplin, Missouri.

[Analyzed by L. G. Eakins.]

	A.	B.
CaO	21·46	28·72
MgO	14·79	17·26
Al_2O_3, Fe_2O_3	1·32	1·03
Insoluble	29·77	11·66
CO_2 (calculated)	33·13	41·55
	100·47	100·22

Second. Seven cherts.

A. Partly altered, from East Hollow, Belleville, Jasper county, Missouri.

B. Altered to "cotton rock," same locality.

C. Unaltered, same locality.

D. Surprise mine, Joplin, Missouri.

E, F. Bonanza shaft, Galena, Kansas.

G. Altered, same locality.

[Analyzed by E. A. Schneider.]

	A.	B.	C.	D.
SiO_2	98·02	98·71	98·17	99·46
Al_2O_3, Fe_2O_3	·48	.43	·83	·29
CaO	·03	·03	·05	·04
MgO	.02	·02	·01	trace
Ign	·42	·50	·78	·34
	99·87	99·69	99·84	100·13

	E.	F.	G.
SiO_2	99·23	98·60	99·13
Al_2O_3, Fe^2O_3	·22	·52	·16
CaO	·02	·10	trace
MgO	trace	trace	.01
Ign	·50	·40	·20
	99·97	99·62	99.50

Digitized by Google

Third. "Jasperite" and "tripoli."
A. Jasperite, from Joplin, Missouri.
B. Jasperite, from Galena, Kansas.
C, D. Tripoli, from Seneca, Newton county, Missouri.

[Analyses by L. G. Eakins.]

	A.	B.	C.	D.
SiO_2	95.77	97·33	98.29	98·93
Al_2O_3, Fe_2O_3	1·84	1·89	·62	·63
CaO	·54	·11	·09	.04
MgO	·24	·09	.....	.....
H_2O	1·17	·77	1·11	·68
	99·56	100·19	100·11	100·28

Fourth. Eleven "tallow clays."
A, B, C, D. From Joplin, Missouri.
E. From Aurora, Missouri.

[Analyzed by T. M. Chatard.]

	A.	B.	C.	D.	E.
Ign	17·19	16·74	17·63	16·95	16·96
Insoluble	40·64	43·07	39·34	39·62	34.04
Soluble Al_2O_3	5·72	7·60	6·17	6·45	10·01
Soluble Fe_2O_3	1·30	1·12	1·16	1·53	3·62
Soluble ZnO	32·46	29·43	34·28	33·55	33·49
Soluble CaO	1·80	1.70	2.13	1.77	2·09
Soluble MgO	.27	·32	·27	·30	·25
	99·38	99·98	100·98	100·17	100.46

F. Cave Springs mine, Jasper county, Missouri.
G. Coon hollow, Boone county, Arkansas.
H. Great Western mine, Granby, Missouri.
I, J, K. Woodcock mine, Granby.

[Analyses by H. N. Stokes.]

	F.	G.	H.	I.	J.	K.
Ign	10·37	8·36	8·22	7·99	9·19	7·52
Insoluble	51·64	47·20	44·14	39·12	44·79	40·03
Soluble Al_2O_3	7·38	6·34	10·78	8·21	8·93	6·46
Soluble Fe_2O_3	10·34	4·40	3·89	2·75	5·98	3·49
Soluble ZnO	14·35	30·50	29·54	38·59	26·23	38·90
Soluble CaO	1·55	1·91	2·65	2·77	2·01	2·56
Soluble MgO	·35	·75	·90	·78	·46	·42
	95·98	99·46	100·12	100·21	97·59	100·28

In these analyses the terms insoluble and soluble refer to solubility of the material in aqueous hydrochloric acid.

Digitized by Google

TWO FELDSPARS.

[Separated from the elæolite-syenite of Litchfield, Maine, by W. S. Bayley; analyzed by W. H. Melville.]

	Sp. gr., 2·56.	Sp. gr., 2·622.
H_2O	·17	·09
SiO_2	65 14	68·28
Al_2O_3	18·19	19·62
FeO	·25	·23
CaO	·33	·31
MgO	·16	·09
K_2O	14·14	·39
Na_2O	1·68	10·81
	100·06	99·82

SIX SANDSTONES.

A, B, C. "Peebles-Henley stone," from Portsmouth, Ohio.

[Analyzed by H. N. Stokes. Alkalies probably present, but not sought for.]

	A.	B.	C.
SiO_2	90·40	89·32	87·12
Al_2O_3	5·15	5·52	5·96
Fe_2O_3	·65	·87	·85
FeO	·27	·35	·85
MgO	·28	·51	·73
Ign	·99	1·49	2·00
	97·74	98·06	97·51
Insoluble in HCl	98·00	96·90	95·52

D. Brown sandstone, Hummelstown, Pennsylvania.
E. Potsdam sandstone, Sauk county, Wisconsin.
F. Banded sandstone, Peoa, Utah.

[Analyses by E. A. Schneider.]

	D.	E.	F.
SiO_2	88·13	99·42	96·60
Al_2O_3	5·81	·31	2·02
Fe_2O_3	1·77		
FeO	·31	.....	.....
CaO	·20	.....	·04
MgO	·53	.....	·08
K_2O	2·63	.....	.....
Na_2O	·06	.....	.....
H_2O	·49	·18	·40
	99·93	99·91	99·14

Digitized by Google

SEVEN MARBLES AND DOLOMITES.

A and B. From Happy valley, Georgia.
C. From Rutland, Vermont.

[Analyses by L. G. Eakins.]

	A.	B.	C.
CaO	53·91	53·69	50·79
MgO	·83	·83	trace
Al_2O_3	·17	·15	·39
FeO	·05	·06	·14
CO_2	43·16	43·13	39·80
H_2O	·13	·17	1·01
Insoluble	1·84	2·01	8·00
	100·09	100·04	100·13

Analyses of portion insoluble in hydrochloric acid.

	A.	B.	C.
SiO_2	58·21	55·48	56·69
Al_2O_3	7·37	15·58	31·16
FeO	·31	trace	2·13
CaO	12·53	14·52	2·68
MgO	20·42	12·88	3·27
	98·84	98·46	95·93

D. Marble from Lee, Massachusetts.
E. Compact gray limestone, from Greason, Pennsylvania.
F. Dolomite, from Cockeysville, Maryland.
G. Crystalline limestone, Eureka, Nevada.

[Analyses by E. A. Schneider.]

	D.	E.	F.	G.
CaO	30·88	39·26	29·08	30·60
MgO	21·42	9·00	20·30	21·69
Al_2O_3, Fe_2O_3	·24	.....	·40	.....
CO_2	46·72	38·82	44·26	47·13
H_2O, 105°	.....	·18	.....	.....
Insoluble	·19	11·07	5·57	·53
Organic matter	.....	·75	.....	.....
	99·45	99·08	99·61	99·95

NINE ROCKS FROM MARYLAND.

[Collected by G. H. Williams; analyzed by W. F. Hillebrand.]

A. Granite, from Guilford.
B. Granitite, Sykesville.

Digitized by Google

C. Hornstone, from contact with limestone, Sykesville.
D. Dissolved inclusion, Sykesville.

	A.	B.	C.	D.
SiO_2	72·57	71·45	67·02	47·35
Al_2O_3	15·11	14·36	13·77	29·76
Fe_2O_3	·59	3·07	4·64	2·94
FeO	1·02	2·78	1·02	3·15
CaO	1·65	1·58	11·09	2·20
MgO	·30	1·17	·65	1·60
K_2O	4·33	3·28	·09	6·83
Na_2O	3·92	1·95	·66	2·84
H_2O	·47	1·30	1·16	3·15
	99·96	99·94	100·10	99·82

E, F, G. Granitites.
H, I. Gneisses.
E. From Woodstock, the remainder from Dorsey's run.

	E.	F.	G.	H.	I.
SiO_2	71·79	62·91	70·45	57·33	48·92
Al_2O_3	15·00	19·13	15·98	15·31	16·57
Fe_2O_3	·77	·98	·75	3·39	4·21
FeO	1·12	3·20	1·84	8·19	9·18
CaO	2·50	4·28	2·60	3·95	9·69
MgO	·51	1·69	·77	4·36	5·98
K_2O	4·75	3·38	3·59	4·57	1·56
Na_2O	3·09	3·94	3·83	1·22	2·47
H_2O	·04	·63	·45	1·80	1·68
	100·17	100·14	100·26	100·12	100·26

Manganese and traces of lithia present in all. SrO and BaO not looked for. TiO_2 and P_2O_5, if present, are included with the alumina.

ERUPTIVE ROCK FROM KENTUCKY.

From a dike in Crittenden county.

[Analyzed by W. F. Hillebrand. Material dried at 100°.]

SiO_2	33·84
TiO_2	3·78
Al_2O_3	5·88
Cr_2O_3	·18
Fe_2O_3	7·04
FeO	5·16
MnO	·16
NiO	·10
CoO	trace
CaO	9·46
BaO	·06
MgO	22·96
K_2O	2·04

Digitized by Google

Na_2O	·33
H_2O	7·50
P_2O_5	·89
Cl	·05
CO_2	·43
	99·86

FOUR GRANITES FROM MISSOURI.

From NE. ¼ Sec. 6, T. 33, R. 5 E.

[Analyses by W. H. Melville.]

	A.	B.	C.	D.
SiO_2	69·94	72·35	71·33	71·88
TiO_2	·25	·44	·55	·22
P_2O_5	·13	·13	·16	·15
Al_2O_3	15·19	13·78	12·55	12·88
Fe_2O_3	1·88	1·87	3·75	3·05
FeO	·60	·36	·85	1·05
NiO	trace	·20	·15	·02
MnO	·03	·06	·04	trace
CaO	1·15	·87	·94	1·13
MgO	·92	·42	·58	·33
Na_2O	3·95	4·14	4·52	4·21
K_2O	4·29	4·49	4·20	4·46
H_2O, 100°	·14	·22	·12	·17
H_2O, ignition	·85	·54	·30	·26
	99·32	99·87	100·04	99·81

THREE ROCKS FROM MINNESOTA.

A. Hypersthene gabbro from SE ¼ Sec. 20, T. 65 N., R. 4 W.
B. Olivine gabbro, SE. ¼ Sec. 19, T. 63, R. 9 W.
C. Olivine gabbro, S. quarter post, Sec. 35, T. 61 N., R. 12 W.

[Anaylses by H. N. Stokes.]

	A.	B.	C.
SiO_2	46·96	45·66	46·45
TiO_2	·62	·92	1.19
P_2O_5	·03	·05	·02
Al_2O_3	14·13	16·44	21·30
Fe_2O_3	·76	·66	·81
Cr_2O_3	trace	trace	.....
FeO	14·95	13·90	9·57
NiO	·06	·16	·04
MnO	·93	trace	trace
CaO	2·32	7·23	9·83
MgO	15·97	11·57	7·90
K_2O	1·68	·41	·34
Na_2O	·35	2·13	2·14
H_2O, 105°	·07	·07	·14
H_2O, above 105°	1·26	·83	1·02
	100·09	100·03	100·75

Digitized by Google

ROCKS FROM COLORADO.

A, B, C. Three rocks from Gunnison county; A, Mount Marcellina; B, Storm ridge; C, Mount Carbon.

[Analyses A and C by T. M. Chatard; B by L. G. Eakins.]

	A.	B.	C.
SiO_2	62·85	61·42	65.36
TiO_2	·41	·37	·52
P_2O_5	·48	·14	·25
Al_2O_3	16·21	17·69	15·48
Fe_2O_3	3·08	4·24	3·09
FeO	1·46	1·74	1·21
MnO	·15	·19	·19
BaO	·11	·09	·08
CaO	4·72	5·29	4·14
MgO	1·47	1·81	1·53
K_2O	3·10	3·19	3·41
Na_2O	3·49	3·14	3·58
H_2O, 105°	·29	·97	·82
H_2O, ignition	2·03		·70
	99·85	100·28	100·36

D. Rhyolite from Mount Robinson, Custer county.

[Analysis by L. G. Eakins. Contains much diaspore.]

	D.
SiO_2	69·67
Al_2O_3	13·72
CaO	·07
MgO	trace
K_2O	2·44
Na_2O	·34
H_2O	4·73
SO_3	9·27
	100·24

E, F, G, H, I. Spherulites from Custer county; E, G, H, from Rosita; F, I, from Silver cliff.

[Analyses by L. G. Eakins.]

	E.	F.	G.	H.	I.
SiO_2	74·47	83·91	80·61	79·21	78·77
Al_2O_3	13·87	9·51	10·94	12·24	12·46
CaO	·51	·19	·26	·43	·34
MgO	trace	trace	·09	·11	·09
K_2O	7·46	5·06	3·02	5·26	5·84
Na_2O	2·10	·62	2·90	2·58	2·12
H_2O	1·88	·69	2·20	·66	·70
	100·29	100·01	100·02	100·49	100·32

Digitized by Google

ROCKS FROM MONTANA.

Received from G. P. Merrill. A, from hills northwest of Red Bluff; B, between Antelope and South Bowlder creeks; C, hills east of South Bowlder creek; D, near North Meadow creek; E, near North Meadow creek; F, northwest of Red Bluff.

[Analyzed by L. G. Eakins.]

	A.	B.	C.	D.	E.	F.
SiO_2	48·95	50·82	50·03	46·13	51·83	59·48
TiO_2	·81	·59	·61	·73	·29	.93
Al_2O_3	5·69	11·44	14·08	4·69	7·98	16·37
Cr_2O_3	·05	·03	trace	·04	.31	.03
Fe_2O_3	1·20	·25	2·92	.73	1·48	3·21
FeO	12·11	8.94	6·11	10·87	8·28	3·17
MnO	·08	·19	.08	trace	trace	·19
NiO	·16	trace	trace	·09	·11	trace
CaO	5·33	8·14	7·46	4·41	5·26	4·88
MgO	23·49	14·01	10·73	25·17	24·10	3·29
BaO	trace	·06	.04	trace	.....	·13
K_2O	·79	3·45	2·64	trace	·06	2·81
Na_2O	1·58	1·79	1·46	·08	·35	3.30
H_2O	·18	·58	3·70	1·38	·29	2·01
P_2O_5	·12	·20	·42	·07	·09	·41
S	.....	.....	.....	·24	.....	.....
	100·54	100·49	100·28	100·63	100·43	100·21

Rock and separations from top of Square butte, Bear Paw mountains.

[Analyses by W. H. Melville.]

	Rock.	Hornblende.	Sp. gr. 2·265.	Sp. gr. 2·255.
SiO_2	56·45	38·41	41·56	49·54
TiO_2	·29	.....	.....	.....
P_2O_5	·13	.....	.....	.....
Cl	·43	.....	4·79	1·67
Al_2O_3	20·08	17·65	29·48	25·07
Fe_2O_3	1·31	3·75	.....	.....
FeO	4·39	21·75	.49	·40
NiO	trace	trace	.....	.....
MnO	·09	·15	.....	.....
CaO	2·14	10·52	·49	·22
MgO	·63	2·54	·15	.20
Na_2O	5·61	2·95	19·21	15·32
K_2O	7·13	1·95	·91	·89
H_2O, 100°	·26	.....	·45	undet.
H_2O, above 100°	1·51	·24	3·73	undet.
	100.45	99·91	101·26	93·31
Less O=Cl	·10	.....	1·08	·38
	100·35	.....	100·18	92·93

Digitized by Google

Two rocks from the Crazy mountains: A, theralite, Gordon's butte; B, porphyritic theralite, Elbow creek.

[Analyzed by E. A. Schneider.]

	A.	B.
SiO_2	44·31	47·67
Al_2O_3	17·20	18·22
Fe_2O_3	4·64	3·65
FeO	3·73	3·85
CaO	10·40	8·03
MgO	6·57	6·35
MnO	·10	·28
K_2O	3·64	3·82
Na_2O	4·45	4·93
H_2O, 105°	·77	·38
H_2O, ign	3·30	2·97
	99·11	100·15

Four rocks from the Crazy mountains: A, green dike parallel to theralite; B, divide between first and second large creeks west of Smith's; C, Peaked butte; D, green dike north of long theralite dike.

[Analyzed by W. H. Melville.]

	A.	B.	C.	D.
SiO_2	58·70	62·17	59·66	64·33
TiO^2	trace	trace	trace	trace
P_2O_5	·10	·11	·14	trace
Al_2O_3	19·26	18·58	16·97	17·52
Fe_2O_3	3·37	2·15	3·18	3·06
FeO	·58	1·05	1·15	·94
MnO	·10	trace	·19	·35
CaO	1·41	1·57	2.32	·56
MgO	·76	·73	·80	·34
Na_2O	8·55	7·56	8·38	7·30
K_2O	4·53	3·88	4·17	4·28
H_2O, 105°	·07	·07	·07	.04
H_2O, ign	2.57	1·63	2·53	·95
	100·00	99·50	99·56	99·67

Digitized by Google

ROCKS FROM ARIZONA.

A series of four from the Santa Maria basin.

[Analyzed by W. F. Hillebrand.]

	1.	2.	3.	4.
SiO_2	49·36	55·35	57·04	57·48
TiO_2	·98	·87	·94	·94
Al_2O_3	16·35	12·71	13·66	14·09
Fe_2O_3	2·93	4·67	4·96	5·21
FeO	8·55	2·06	1·77	1.35
MnO	·19	.08	·17	·09
(NiCo)O	.05	·05	·07	·08
CaO	10.08	5·77	6·23	6·05
SrO	none	trace	trace	trace
BaO	·04	·19	·22	·23
MgO	7·06	6·29	4·43	3·49
K_2O	·82	4·86	4·95	4·69
Na_2O	2·67	2·65	3·08	3·00
H_2O, 100°	·22	2·67	1·11	1·20
H_2O, above 100°	·65	1·18	1·10	1·37
P_2O_5	·30	·58	·63	·65
Cl	undet.	undet.	undet.	undet.
Li_2O	none	trace	trace (?)	none
	100·25	99·98	100·36	99·92

ROCK FROM EUREKA, NEVADA.

An andesitic pearlite.

[Analysis by W. H. Melville.]

SiO_2	65·13
TiO_2	·58
P_2O_5	·23
Al_2O_3	15·73
Fe_2O_3	2·24
FeO	1·86
NiO	·07
MnO	trace
CaO	3·62
MgO	1·49
K_2O	3·96
Na_2O	2·93
H_2O, 105°	·52
H_2O, above 105°	1·91
	100·27

Digitized by Google

ROCKS FROM CALIFORNIA.

Three from Mount Diablo: A, diabase, somewhat altered; B, diabase, fresh; C, pyroxenite.

[Analyzed by W. H. Melville.]

	A.	B.	C.
SiO_2	51·58	52·06	53·25
TiO_2	1·05	·47	trace
P_2O_5	·24	·13	.....
Al_2O_3	14·99	14·34	2·80
Cr_2O_3	.....	.....	·54
Fe_2O_3	2·04	2·11	·60
FeO	8·36	7·74	5·93
NiO	.....	.....	·07
MnO	trace	trace	·09
CaO	8·59	8·05	16·22
MgO	6·51	9·26	19·91
Na_2O	3·08	1·74	·19
K_2O	·31	·73	trace
H_2O, 100°	·34	·59	·05
H_2O, above 100°	2·67	2·90	·24
	99·76	100·12	99·98

Four collected by H. W. Turner: A, Table mountain, basalt, Tuolumne county; B, basalt, Plumas county; C, dolerite, Plumas county; D, quartz porphyrite, Plumas county.

[Analyzed by W. F. Hillebrand.]

	A.	B.	C.	D.
SiO_2	56·19	50·56	53·91	73·25
TiO_2	·69	1·71	·52	trace
Al_2O_3	16·76	14.71	17·95	13·25
Fe_2O_3	3·05	3·54	2·21	.....
FeO	4·18	8·90	4·80	1·74
MnO	·10	·13	·10	trace
CaO	6·53	7·58	10·40	2·23
BaO	·19	·25	.05	trace
MgO	3·79	4·07	5·52	·28
K_2O	4·46	2·10	1·34	3·79
Na_2O	2·53	2·94	2·90	2·69
H_2O, 100°	·34	1·06	·20	·07
H_2O, above 100°	·66	1·12	·20	1·03
P_2O_5	·55	1·14	·21	trace
CO_2	.....	.....	.....	1.05
FeS_2	.....	.....	.....	·58
	100·02	99·81	100·31	99·96

Also traces of lithia and strontia.

Digitized by Google

SINTER FROM QUEENSLAND.

From the Mount Morgan gold mine. Analyzed for comparison with the sinters from the Yellowstone National Park.

[Analysis by E. A. Schneider.]

SiO_2	94·02
$Al_2O_3 + Fe_2O_3$	2·27
CaO	·07
MgO	trace
H_2O, 105°	1·07
H_2O, ignition	2·29
	99·72

TWO CLAYS FROM FLORIDA.

A, from Tampa; B, from Lakeland.

[Analyses by L. G. Eakins.]

	A.	B.
SiO_2	70·78	80·39
$Al_2O_3 + Fe_2O_3$	11·33	15·03
CaO	2·18	1·22
H_2O	14·55	4·34
	98·84	100·98

IRON ORES FROM WEST VIRGINIA.

[Analyses by H. N. Stokes.]

First, from Cherry run, near the Potomac river.

H_2O, 105°	·81
Fe	50·16
Mn	·04
S	·06
P	·80
Insoluble	14·43

Second, a series from Tazewell county.

	Taylor.	Hornets Nest.	Dial Rock.	Boulder.	Adds Ridge.
Moisture, 105°	1·67	1·59	1·10	3·17	1·24
Fe	36·81	56·48	54·01	56·07	40·75
Mn	5·42	·47	·26	trace	.....
S	·09	·03	·09	·25	·08
P	·04	1·08	·95	·91	trace
Insoluble	26·19	1·85	4·26	2·63	32·37

Digitized by Google

COAL AND COKE FROM WEST VIRGINIA.

From the Thomas Vein, Davis. A, upper coal; B, middle coal; C, lower coal; D, 48-hour coke; E, 72-hour coke.

[Analyses by L. G. Eakins.]

	A.	B.	C.	D.	E.
Fixed carbon	65·60	65·99	72·76	87·08	90·05
Volatile hydrocarbons	22·87	23·88	22·90	·95	1·16
Moisture	·64	·68	·96	·23	·15
Ash	10·89	9·45	3·38	11·74	8·64
	100·00	100·00	100·00	100·00	100·00
Sulphur	·64	1·39	·59	·63	·70
Phosphorus	·06	·02	·01	·06	·04

TWO COALS FROM UTAH.

A, Little Cottonwood gulch, near Salt Lake city; B, Wasatch mountains.

[Analyses by L. G. Eakins.]

	A.	B.
Fixed carbon	85·83	42·81
Volatile hydrocarbons	7·15	24·60
Moisture	2·98	25·57
Ash	4·04	7·02
	100·00	100·00

Digitized by Google

Digitized by Google

INDEX.

	Page.
unite	62
trophyllite	41-42
rous sulphide	56-61
ickstrom, cited	41
otite	11-12, 13
smuthinite	40
ögger, W. C., cited	41, 42
lcium molybdate	34-37
atard, T. M., analyses by	64, 69
ert	63
rke, F. W., on the constitution of certain micas, etc	11-21
ıy	64, 74
al	75
ke	75
lloidal sulphide of gold	56-61
oke, cited	14
oss, Whitman, quoted on thin sections of tscheffkinite	42-43
lafontaine, cited	29
marcay, cited	29
aspore	62
lomite	63, 66
kins, L. G., analyses by	62, 63, 64, 66, 69, 70, 74, 75
gle, Horace M., acknowledgments to	42
uptive rocks	67
dspar	65
bbro	68
eiss	67
anite	66
anitite	66, 67
llite	14, 15, 16
ılandite	62
lden, W. E., aid by	22, 23
lebrand, W. F., on uraninite	22, 25
on the isormorphism and composition of thorium and uranous sulphates	26-31
analyses by	67, 72, 73
ffman, G. C., acknowledgments to	24
rnstone	67
n ore	74
sperite	64
nig, cited	41
ını	14, 15, 16

	Page.
Limestone	66
Lindgren, Waldemar, aid by	12, 14
Lösch, A., acknowledgments to	24
Marble	66
Melville, W. H., on crystallography of thorium and uranous sulphates	31-33
on powellite-calcium molybdate	34-37
analyses by	65, 68, 70, 71, 72, 73
Merrill, G. P., quoted	19, 20
Meteorites, analyses	45, 46
Mica from Henderson county, N. C	11, 12, 13
Micas, paper on constitution of	11-21
Natrolite	38
Nivenite	22, 23
Packard, R. L., acknowledgments to	34
Painterite	17-19
Powellite	34-37
Protovermiculite	11-12, 13
Rammelsburg, cited	29
Rhyolite	69
Roozeboom, cited	29
Sandstone	65
Schneider, E. A., on the constitution of certain micas, etc	11-21
on the colloidal sulphides of gold	56, 61
analyses by	63, 65, 71, 74
Sinter	74
Smithsonite	62
Spessartite garnet	39
Spherulites	69
Stokes, H. N., on the action of phosphorus oxychloride on the ethers and chlorhydrines of silicic acid	47-55
analyses by	62, 64, 68, 74
Therolite	71
Thorium and uranous sulphates, paper on isomorphism and composition of	26-33
Tourmaline	39
Traube, H, cited by	37
Tripoli	64
Tscheffkinite	42
Tschermak, cited	16, 17
Uranium sulphate, crystalline form of	32
Uranium-thorium sulphate	32
Uraninite	22-25
Vermiculite	11-21

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 91

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

RECORD

OF

ORTH AMERICAN GEOLOGY FOR 1890

BY

NELSON HORATIO DARTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

Digitized by Google

Digitized by Google

RECORD OF NORTH AMERICAN GEOLOGY FOR 1890.

By Nelson Horatio Darton.

INTRODUCTORY.

This work is the continuation of the record for 1887–1889,[1] inclusive, and includes publications received during the year 1890.

The literary scope of this record includes geologic publications printed in North America, and publications on North American geology wherever printed. Purely paleontologic or mineralogic papers are not included.

The entries are comprised in the three following classes, all arranged in a single alphabetic sequence:

I. *Principal entries.*—Consisting of full titles of separate contributions classified by authors, together with an abbreviated reference to the containing publication and a short note descriptive of the geologic contents. Imprint dates are given only when other than 1890, and size of page when other than octavo. The extent of papers less than a page in length is indicated thus: $\frac{1}{8}$ p., $\frac{1}{4}$ col., 3 lines.

II. *Titles of containing publications.*—Entered as headings under which authors' names and short titles of the contained papers are listed in their order of precedence.

III. *Subject references.*—Each consisting of a condensed title of paper, and the author's name for cross-reference to a principal entry. These are essentially index references, but they are entered under a limited number of headings, of which a classified key is given below.

[1] Bulletin U. S. Geol. Survey, No. 75, pp. 173. Washington, 1891.

Digitized by Google

CLASSIFIED KEY TO THE SUBJECT ENTRIES.

(1) GEOGRAPHIC SUBJECTS.

Alabama.
Alaska, and the other States and Territories.
Africa.
Asia.
Canada (including all of British Columbia).
Central America.
Europe.
Hawaiian Islands.
Mexico.
South America.

(2) STRATIGRAPHIC SUBJECTS.

Archean and Algonkian, with sub-headings as follows:
- Eastern Canada.
- Lake Superior to Lake Huron region.
- New England.
- New York to Georgia.
- Western United States.
- Nomenclature.

Cambrian, with sub-headings as follows:
- Canada.
- New York and New England.
- Pennsylvania to Virginia.
- Illinois.
- Great Lakes region.
- Western United States.
- Nomenclature.

Carboniferous (including Permian), with sub-headings as follows:
- Canada.
- New England.
- Appalachians to the Mississippi.
- Iowa, Missouri, Kansas.
- Arkansas to Mexico.
- Rocky Mountain region.
- Arizona.
- Central America.
- California.

Digitized by Google

Cretaceous, with sub-headings as follows:
- Atlantic Coast region.
- Canada.
- Great Plains and Rocky Mountain region.
- Texas region.
- Mexico.
- Kentucky.
- Pacific coast.
- South America.

Devonian, with sub-headings as follows:
- Alabama.
- Canada.
- Central America.
- England.
- Illinois.
- Iowa.
- Kentucky.
- Maine.
- Massachusetts.
- New Jersey.
- New York.
- Ohio and Indiana.
- Pennsylvania.
- Tennessee.
- Virginia and Maryland.
- Western United States.
- Nomenclature.

Jura-Trias, with sub-headings as follows:
- Canada.
- Central America.
- Newark formation (Connecticut to North Carolina).
- Western United States.
- Nomenclature.

Pleistocene, with sub-headings as follows:
- Alaska.
- Appalachians to Mississippi basin.
- Atlantic Coast region.
- Central America.
- General.
- Great Lakes region and eastern Canada.
- Mississippi basin to Rocky Mountains.
- Rocky Mountains to Pacific coast.
- Western Canada.

Digitized by Google

Silurian, with sub-headings as follows:
- Appalachians (Maine to Alabama).
- Canada.
- Central and Western States.
- Nomenclature.

Tertiary, with sub-headings as follows:
- Atlantic Coast plain.
- Gulf States (Florida to Texas).
- Arkansas to Kansas.
- British Columbia.
- Central and Western United States.
- California and Oregon.
- Mexico.
- Central America.
- South America.

(3) OTHER SUBJECTS.

Geologic philosophy, with sub-headings as follows:
- Petrology.
- Glaciology.
- Physiographic geology.
- Earth crust deformation.
- Chemical and chemico-organic deposition.
- Geologic climate.
- Volcanism.
- Miscellaneous.

Petrography.

Digitized by Google

LIST OF PUBLICATIONS EXAMINED.

American Academy of Arts and Sciences, Proceedings, vol. 24.
American Association for the Advancement of Science, Proceedings, vol. 38. Salem, Mass.
American Geologist, vols. 5, 6. Minneapolis, Minn.
American Journal of Science, 3d series, vols. 39, 40. New Haven, Conn.
American Museum of Natural History, Bulletin, vol. 2, Nos. 3, 4; vol. 3, No. 1, pp. 1–194. New York, N. Y.
American Naturalist, vol. 23, November and December; vol. 24. Philadelphia, Pa.
American Philosophical Society, Proceedings, vol. 27, No. 131; vol. 28, Nos. 132–134. Philadelphia, Pa.
——— Transactions, vol. 16, new series, part 3. Philadelphia, Pa.
Appalachia, vol. 6, Nos. 1, 2. Boston, Mass.
Boston Society of Natural History, Proceedings, vol. 24, pp. 355 to end; vol. 25, pp. 1–80. Boston, Mass.
British Association for the Advancement of Science, Report of fifty-ninth meeting. London.
California Academy of Science, vol. 2. San Francisco.
California, State Mineralogist, Ninth and Tenth Annual Reports. Sacramento.
Canada, Geological and Natural History Survey, Annual Report, new series, vol. 3, 1887–'88, 2 parts. Montreal.
Canada, Royal Society, Transactions, vol. 7. Montreal.
Canada, Report of Commission on Mineral Resources of Ontario.
Canadian Institute, Proceedings, 3d series, vol. 7. Toronto.
Canadian Record of Science, vol. 3, Nos. 7, 8; vol. 4, Nos. 1–4.
Cincinnati Society of Natural History, Journal, vol. 12, No. 4; vol. 13, Nos. 1–3. Cincinnati, Ohio.
Colorado Scientific Society, Proceedings, vol. 3, part 2. Denver.
Connecticut Academy of Arts and Sciences, Transactions, vol. 8, part 1. New Haven.
Denison University, Scientific Laboratories, Bulletin, vol. 5. Granville, Ohio.
Deutsche geologische Gesellschaft, Zeitschrift, vol. 40, No. 4; vol. 41, Nos. 1–3. Berlin.
Edinburgh Geological Society, Transactions, vol. 6, parts, 1, 2. Edinburgh.
Elisha Mitchell Scientific Society, Journal, 1889, part 2; 1890, part 1. Raleigh, N. C.
Essex Institute, Bulletin, vol. 21, Nos. 7–12; vol. 22, Nos. 1–6. Salem, Mass.
Engineering and Mining Journal, vol. 49, 50. New York.
Forum, 1890. New York.
Geological Magazine, new ser., decade III, vol. 7. London.
Geological Society of America, Bulletin, vol. 1. Washington, D. C.
Geological Society, Quarterly Journal, vol. 46. London.
Geologiska Föreningens i Stockholm, Förhandlingar, vol. 11, Nos. 5–7; vol. 12. Nos. 1–4.
Georgia, Bulletin Experiment Station, 1890.
Harvard College, Museum of Comparative Zoölogy, Bulletin, vol. 16, Nos. 5, 7, 8; vol. 17, No. 6; vol. 18; vol. 19, Nos. 1–4; vol. 20, Nos. 1–5, 7.
Iowa Academy of Science, Proceedings, 1887–'89.

Digitized by Google

Iowa State University, Laboratories of Natural History, Bulletin, vol. 1, Nos. 2–4; vol. 2, No. 1. Iowa City.
Johns Hopkins University, Circulars, Nos. 78–84. Baltimore, Md.
Kansas Academy of Science, Transactions, vol. 12, part 1. Topeka.
Liverpool Geological Association, Journal, vol. 9. Liverpool.
Liverpool Geological Society, Proceedings, vol. 6, part 1. Liverpool.
Liverpool Literary and Philosophical Society, Proceedings, vol. 41. Liverpool.
Manchester Geological Society, Transactions, vol. 20, parts 9–17. Manchester.
Missouri, Geological Survey, Bulletins Nos. 1–3. Jefferson City.
National Geographic Magazine, vol. 2. Washington, D. C.
Nature, 1890. London.
Neues Jahrbuch, 1890. Stuttgart.
New Brunswick Natural History Society, Bulletin, vol. 9. Saint John.
New Jersey Geological Survey, Annual Report of the State Geologist for 1889. Trenton.
New York Academy of Sciences, Annals, vol. 4, No. 12; vol. 5. New York.
——— Transactions, vol. 9; vol. 10, Nos. 1–3. New York.
New York, Commissioners of the State Reservation at Niagara, Sixth Report. Albany.
New York State Museum, Annual Reports, 41–42. Albany.
——— Bulletin, No. 7. Albany.
Ohio Geological Survey, First Annual Report (3rd organization). Columbus.
Ottawa Naturalist, vol. 3, No. 4; vol. 4, Nos. 1–9. Ottawa, Canada.
Pennsylvania Geological Survey, Annual Report for 1887. Harrisburg.
——— Seventh Report on Oil and Gas. Harrisburg.
Philadelphia Academy of Natural Science, Proceedings, 1889, part 3; 1890, parts 1-2. Philadelphia, Pa.
Popular Science Monthly, 1890. New York.
School of Mines Quarterly, vol. 11, Nos. 2–4; vol. 12, No. 1. New York.
Science, vols. 15, 16. New York.
Scientific American Supplement, vols. 29, 30. New York.
Scottish Geographical Magazine, vol. 6. Edinburgh.
Smithsonian Institution, Annual Report, 1886, part 2; 1887, part 2, 1888, parts 1. 2.
Société géologique de France, Bulletin, 3e série, vol. 16, No. 10; vol. 17, Nos. 1-9. Paris.
Société géologique du Nord, Annales, vol. 16, Nos. 5, 6; vol. 17, Nos. 1–3. Lille.
Technology Quarterly, vol. 3, Nos. 1–3. Boston, Mass.
Texas Geological Survey, Bulletin No. 4. Austin.
——— First Annual Report. Austin.
U. S. Geological Survey, Bulletins, Nos. 54–64, 66–70. Washington.
——— Monographs, vols. 1, 15, 16. Washington.
——— Annual Reports, J. W. Powell, Eighth and Ninth, 1886–'88.
U. S. National Museum, Proceedings, vol. 12. Washington, D. C.
Vassar College Institute, Transactions, vol. 5. Poughkeepsie, N. Y.
Wagner Free Institute, Transactions, vols. 2, 3. Philadelphia.
Warren's New Physical Geography.
Washburn College Laboratory, Bulletin, vol. 2, No. 11. Topeka, Kans.
Washington Philosophical Society, Bulletin, vol. 11, pp. 173–358. Washington, D. C.
Wyoming, Report of the Territorial Geologist, January, 1890. Cheyenne.
Yorkshire Geological and Polytechnic Institute, Proceedings, new series, vol. 11, part 2.

Digitized by Google

RECORD.

A.

ADAMS, F. D. Notes on the lithological character of some of the rocks collected in the Yukon district and adjacent northern portion of British Columbia.

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report B, pp. 235-240. 1888.

Consists entirely of petrographic descriptions.

—— [Summary of observations in 1887 in Montcalm and Joliette counties.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report A, pp. 27-28. 1888.

Includes a brief description of the relations of the anorthosite, and evidence as to its eruptive nature.

—— [Account of explorations in the eastern townships of Quebec.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report A, pp. 84-85. 1888.

Includes brief summary regarding the relations of the crystalline rocks.

Africa. Banket deposits of the Witwatersrand, CURTIS.

De Kaap Transvaal gold-fields, FURLONGE.

Nile and the desert, BOLTON.

AGASSIZ, Alexander. Note [on coral reefs of southern Florida, and their relation to the growth of the peninsula].

Harvard College, Mus. Comp. Zool., Bull., vol. 16, pp. 157-158.

Alabama. Analyses of dolomite and clay, HILLEBRAND.

Appomattox formation, MCGEE.

Building stones, MERRILL, G. P.

Pleistocene submergence, MCGEE. SPENCER.

Analyses of sand and white earth from Talladega, CATLETT.

Geology of Mon Louis island, LANGDON.

Alabama—Continued.

Macfarlane's Railway Guide, CAMPBELL. SMITH and GESNER.

Peculiarities in drainage, MCGEE.

Warren's geography, BREWER.

Alaska. Ice cliffs of Kowak river, RUSSELL. CANTWELL.

Surface geology, RUSSELL.

American Association for the Advancement of Science, vol. 38.

North American Mesozoic, WHITE, C. A.

Origin of gneiss, BELL.

Level of no strain in crust of the earth, CLAYPOLE.

Trap ridges of East Haven, Branford, Connecticut, HOVEY, E. O.

Devonian of Devonshire, WILLIAMS, H. S.

Ogishke conglomerate, WINCHELL, A.

Origin of Keewatin ores in Minnesota, WINCHELL, N. H. and H. V.

Eagle Flats formation and basin of Trans-Pecos, Texas, HILL.

Igneous rocks of central Texas, HILL and DUMBLE.

Staked Plains formation, Texas, HILL.

Valley of Upper Canadian, Texas-New Mexico, HILL.

Topographic features of Texas, HILL.

Zircon rocks in Archean of New Jersey, NASON and FERRIER.

Archean northwest of Lake Superior, LAWSON.

Petrography of certain dikes of Rainy Lake region, LAWSON and SHUTT.

Lake ridges of Ohio and glacial drainage in valley of Susquehanna, WRIGHT.

Digitized by Google

American Association, etc.—Cont'd.
Glacial phenomena, Illinois and Indiana, LEVERETT.
Topographic types of northeastern Iowa, MCGEE.
Petroleum belt of Terre Haute, WALDO.
Maquoketa shales in Iowa, JAMES.
Studies of hornblende schist, HITCHCOCK.
Cretaceous of northern Mexico, WHITE, C. A.
Pits and domes of Mammoth Cave, HOVEY, H. C.

AMERICAN GEOLOGIST. The Azoic system.
American Geologist, vol. 5, pp. 106–107, ½ p.
Discussion of definition given in Century Dictionary.

—— The pre-natal history of the geological society of America.
Am. Geologist, vol. 6, pp. 181–194.

—— What constitutes the Taconic range of mountains?
Am. Geologist, vol. 6, p. 247, Pl. VI.
Excerpts, with maps, from various writers in regard to the location of the Taconic mountains.

—— Quebec not in conflict with Taconic.
Am. Geologist, vol. 6, pp. 310–311.
Discussion of the status of the terms.

——, vol. 5.
Geographic features of the Texas region, HILL.
Laurentian as applied to Quaternary, JAMES.
Scolithus flattened by pressure, WANNER.
Extinct volcanoes in Colorado, LAKES.
Islands of Santa Barbara Channel, YATES.
North American Geology and Paleontology by Miller, DANA.
Geology of Rainy Lake Region, LAWSON.
Fossils from Cambro-Silurian of Manitoba, WHITEAVES.
Geological Survey of Minnesota, report for 1888, WINCHELL, A.
Rivers and valleys of Pennsylvania, DAVIS.
Structure of drumlins, UPHAM.
Fossils of the Trinity beds, HILL.
Kansas salt mine, HAY.
Silurian system, MURCHISON.

American Geologist, vol. 5—Continued.
Level of no strain in crust of the earth, CLAYPOLE.
Origin of outlines of the Bermudas, FEWKES.
Extinction of species, MCCREERY.
Glacial lunoid furrows, PACKARD.
Azoic system, AM. GEOLOGIST.
Subaerial decay of rocks, RUSSELL.
Geology of Nantucket, SHALER.
Meeting of Geological Society of America.
Meeting of Boston Society of Natural History.
Well at Dixon, Illinois, TIFFANY.
Well at Le Mars, Iowa, TODD.
Dikes near Kennebunkport, Maine, KEMP.
Triassic traps of Nova Scotia, MARSTERS.
Training of a geologist, BRANNER.
Triassic flora of Richmond, Virginia, MARCOU.
Copper in Animikie rocks of Thunder Bay, LAWSON.
Quicksilver deposits of Pacific slope, BECKER.
Preglacial channels at the falls of the Ohio, BRYSON.
Level of no strain, DAVIS.
Use of terms Laurentian and Newark, HITCHCOCK.
Glacial geology of Irondequoit regions, DRYER.
Session of International Geological Congress, FRAZER.
History of the Quebec group, HUNT, T. S.
Making of Pennsylvania, CLAYPOLE.
Geology of Ontario, BELL.
Note on Duck and Riding Mountains, TYRRELL.
Report on James Bay country, LOW.
Geology of Quebec, ELLS.
Northern New Brunswick and Maine, BAILEY and MCINNES.
Surface geology of New Brunswick, CHALMERS.
Transactions of meeting of Kansas Academy.
Drainage systems of New Mexico, TARR.
Artesian wells in Kansas, HAY.
American Neocomian, MARCOU.

Digitized by Google

American Geologist, vol. 5—Continued.
Survey of Concho country, CUMMINS and LERCH.
Maquoketa shales, JAMES.
Lower and middle Taconic, MARCOU.
Meeting of International Congress of Geologists, HERRICK.
Trenton limestone oil and gas, ORTON.

——, **vol. 6.**
A deserted gorge of the Mississippi, GRANT.
Permo-Carboniferous of Kansas, WOOSTER.
Huronian-Laurentian contact, BARLOW.
Artesian water from the drift, ROLFE.
Non-feldspathic intrusives of Maryland, WILLIAMS, G. H.
Ice cliffs of Kowak River, Alaska, RUSSELL. CANTWELL.
Quaternary history of Mono Valley, RUSSELL.
Use of terms Laurentian and Champlain, MARCOU.
Casts of crinoids from Burlington limestone, ROWLEY.
Sergipe-Alagôas basin of Brazil, BRANNER.
Check list of Cretaceous invertebrates of Texas, HILL.
On the name Laurentian, JAMES.
Carboniferous of central Texas, TARR.
Glaciation of the Cordillera, DAWSON, G. M.
Eruptive rocks of Lake Huron region, FAIRBANKS.
Pre-natal history of the Geological Society of America, AM. GEOLOGIST.
Characteristics of volcanoes, DANA.
Geographic development of northern New Jersey, DAVIS and WOOD.
Geology of Lassen Peak district, DILLER.
Geology of island of Mt. Desert, SHALER.
Thickness of rocks in Central New York, PROSSER.
Artesian wells in the Dakotas, UPHAM.
Cheyenne sandstone and Neocomian shales of Kansas, CRAGIN.
Coal measures of Indian Territory, CHANCE.
Glaciation of eastern Canada, CHALMERS.

American Geologist, vol. 5—Continued.
What constitute the Taconic Mountains? AM. GEOLOGIST.
Exploration of the Indian Territory, HILL.
Texas Cretaceous, HILL.
The Wetwoods, BRYSON.
Taconic iron ores, WINCHELL, N. H. and H. V.
Pilot Knob, HILL. KEMP.
Extension of Iroquois beach, SPENCER.
Relations of State and National Surveys, BRANNER.
Quebec not in conflict with Taconic, AM. GEOLOGIST.
The Iroquois beach, SPENCER.
Glaciation of the Cordillera and Laurentide, CHALMERS.
Cause of the glacial period, UPHAM.
Great quartzite more recent than Olenus schist, HOLST.
Observations on some Canadian rocks, WINCHELL, A.
Reconnaissance in Kansas, HAY.
Geology of Eastern Maine and New Brunswick, BAILEY.
Glacial boundary—Pennsylvania to Illinois, WRIGHT.
Submergence of Isthmus of Panama, UPHAM.
Iroquois beach, DAVIS.

American Journal of Science, vol. 39.
Devonian system of Devonshire, WILLIAMS, H. S.
Zinciferous clays of Missouri, SEAMON.
Origin of normal faults, READE.
North American Geology and Paleontology, DANA.
12th Report Minnesota Survey, DANA.
Fossils in Columbia County, New York, BISHOP.
Cretaceous, San Carlos Mountain, Mexico, WHITE, C. A.
Fossils in Dutchess County, New York, DWIGHT.
Cretaceous plants from Martha's Vineyard, WHITE, D.
Review of Ells's report on Quebec, WALCOTT.
Tracks in Animikie rocks, SELWYN.
Hercynian fauna, WALCOTT.
Sedgwick and Murchison, Cambrian and Silurian, DANA.

Digitized by Google

American Journal of Science—Cont'd.

Cretaceous of British Columbia, DAWSON, G. M.

Recent rock flexure, CRAMER.

Calciferous formation in Champlain Valley, BRAINERD and SEELY.

Geological survey of Canada, Reports, vol. 3, DAWSON, G. M.

Sandstones of Fernando de Noronha, BRANNER.

Dikes in central Appalachian, Virginia, DARTON. DILLER.

Soda-granite and quartz-keratophyre, Pigeon Point, BAYLEY.

Topographic features of central Texas, TARR.

Subaerial decay of rocks, DANA.

Diatom beds in Yellowstone Park, WEED.

Archean limestone in Norfolk, Conn., CORNISH.

Glacial scratches in Norfolk, Conn., CORNISH.

Characteristics of volcanoes, DANA.

Elementary proof of the earth's rigidity, BECKER.

Minerals of amphibole and pyroxene groups, CROSS.

Archean axes of eastern North America, DANA.

Metamorphic strata of southeastern New York, MERRILL, F. J. H.

History of Mono Valley, California, RUSSELL.

Lower Carboniferous in central Texas, TARR.

Scapolite rock in New Jersey, NASON.

——, vol. 40.

Southern extension of Appomattox formation, MCGEE.

Goniolina in Comanche series of Texas, HILL.

Fayalite in obsidian of Lipari, IDDINGS and PENFIELD.

Post-tertiary deposits of Manitoba, TYRRELL.

Curious occurrence of vivianite, DUDLEY.

Classification of glacial sediments of Maine, STONE.

Silurian graptolites from Maine, DODGE.

Siderite basins of Hudson River epoch, KIMBALL.

American Journal of Science—Cont'd.

American Committees of International Congress, WILLIAMS, H. S.

Potomac or younger Mesozoic flora, FONTAINE.

Rocky Mountain protaxis, DANA.

Cretaceous of Manitoba, TYRRELL.

Geology of Mon Louis Island, LANGDON.

Microscopic structure of oolite, BARBOUR and TORREY.

Clinton group fossils, FOERSTE.

Blandford's address to Geological Society of London, DANA.

Fossils in Hillsdale, New York, DANA.

"Bernardston Series" of upper Devonian rocks, EMERSON.

Keokuk beds at Keokuk, GORDON.

Indianapolis meeting of Geological Society.

Superimposition of the drainage in central Texas, TARR.

Pre-glacial drainage and recent history of western Pennsylvania, FOSHAY.

Long Island Sound in the Quaternary, DANA.

Deformation of Iroquois Beach, SPENCER.

Sand transportation by rivers, GRAHAM.

Cretaceous rocks of northern California, DILLER.

American Museum of Natural History Bulletin, vol. 3.

Calciferous formation in the Champlain Valley, BRAINERD and SEELY.

Fauna of rocks at Fort Cassin, Vermont, WHITFIELD, R. P.

American Naturalist, vol. 23, December.

Silver Lake of Oregon, COPE.

——, vol. 24.

Excavations made by sea-urchins, FAWKES.

Brecciated character of St. Louis limestone, GORDON.

Erosive agents in the arid regions, TARR.

Glacial phenomena in Beaver Valley, FOSHAY and HICE.

Transitional drift of Iowa, WEBSTER.

Digitized by Google

American Philosophical Society, Transactions, vol. 16.
[New series] part 3.
Sergipe-Alagôas basin of Brazil, BRANNER.
Mammalia of Uinta formation, SCOTT.

AMI, Henry M. On the geology of Quebec City.
Science, vol. 16, p.317, 1½ col., 4°.
Abstract, Am. Geologist, vol. 7, p. 71, ½ p, 1891.
Discussion of the horizon of the strata.

Appalachia, vol. 6, Nos. 1, 2.
Madison bowlder, CROSBY.
Ice age in North America, DAVIS.
Volcanoes in Japan, HOLLAND.

Archean and Algonkian.
Eastern Canada, report on Quebec, ELLS.
Review of Ells on geology of Quebec, WALCOTT.
Lake St. John country, CHAMBERS.
Acadian and St. Lawrence water shed, BAILEY.
Stratigraphy of "Quebec group," ELLS.
Eastern townships of Quebec, ADAMS.
Pre-Paleozoic surface in Canada, LAWSON.
Serpentines, GIROUX.
Eastern coast of Hudson Bay, LOW.
Geology of Ontario, BELL.
Mistassinni region, LOW.
Between Montreal River and Lake Huron, BELL.
Archean axes of eastern North America, DANA.
Origin of gneiss, BELL.
Hunter Island and Seine River region, SMITH, W. H.
New Brunswick, BAILEY. BAILEY and MCINNES.
North side of St. Lawrence above Quebec, LAFLAMME.
Warren's geography, BREWER.
Eozoon in rocks at St. John, MATTHEW.
Areas of continental progress in North America, DANA.
Macfarlane's Railway Guide, DAWSON, G. M.
Iron ores, HUNT, T. S.
Lake Temiscaming and Montreal River, BELL.
Summary reports of Geological Survey 1887-'88, SELWYN.

Archean and Algonkian—Continued.
Montcalm and Joliette Counties, ADAMS.
Excursion in northern Appalachians, WILLIAMS, G. H.
Gold-bearing rocks in Halifax County FARIBAULT.
Lake Superior to Lake Huron region,
Report on Rainy Lake region, LAWSON.
Petrography of certain dikes of Rainy Lake region, LAWSON and SHUTT.
Archean northwest of Lake Superior, LAWSON.
Eruptives of Lake Huron region, FAIRBANKS.
Archean of central Canada, LAWSON.
Geology of Ontario, BELL.
Microscopic examination of rocks from Thunder Bay silver district. BAYLEY.
Pigeon Point, Minnesota, BAYLEY.
Report—Lake Superior division, U. S. Geol. Survey, IRVING. VAN HISE.
Pre-Cambrian of the Black Hills, VAN HISE.
Geology of the northwest of Lake Superior, HARVEY.
Origin of ores of Keewatin in Minnesota, WINCHELL, N. H. and H. V.
Position of Ogishke conglomerate, WINCHELL, A.
Results of Archean studies, WINCHELL, A. VAN HISE.
Huronian-Laurentian contact north of Lake Huron, BARLOW.
Huronian and Laurentian rocks north of Lake Huron, LAWSON.
Tracks in Animikie rocks, SELWYN.
Origin of gneiss, BELL.
Greenstone schists of Marquette-Menominee regions, WILLIAMS, G. H. IRVING.
Copper mining in Michigan, ENG. AND MINING JOUR.
Kamanistiquia silver belt, WOOD.
Observation on some Canadian rocks, WINCHELL, A.
Mines on Lake Superior, INGALL.
Copper in Animikie at Thunder Bay, LAWSON.
Taconic iron ores of Minnesota, WINCHELL, N. H. and H. V.
Analyses of rocks from Menominee River, RIGGS.

Digitized by Google

Archean and Algonkian—Continued.

Analysis of novaculite from Marquette, HILLEBRAND.

Analyses of rocks from Pigeon Point, EAKINS. HILLEBRAND. RIGGS. WHITFIELD, J. E.

Analyses of rocks collected by R. D. IRVING. HILLEBRAND.

Analyses of rocks from Penokee-Gogebic range, CHATARD. EAKINS.

Macfarlane's Railway Guide, DAWSON, G. M. WINCHELL, A.

Analysis of diabase from Michigan, CHATARD.

Warren's geography, BREWER.

Iron ores, HUNT, T. S.

Northern and western British America, Caribou district, British Columbia, BOWMAN.

Mineral wealth of British Columbia, DAWSON, G. M.

James Bay region, LOW.

Lithology of rocks from Yukon district, ADAMS.

Big bend of the Columbia, COLEMAN.

Yukon district, DAWSON, G. M.

Areas of continental progress in North America, DANA.

Yukon and Mackenzie Rivers, McCONNELL.

Macfarlane's Railway Guide, DAWSON, G. M.

New England, Geology of Mount Desert Island, SHALER.

Areas of continental progress in North America, DANA.

Archean axes of eastern North America, DANA.

Eastern Maine, BAILEY.

Granites of Massachusetts, EMERSON.

Essex County, Massachusetts, SEARS.

Geology of Cape Ann, SHALER.

Report—Division of Archean geology, U. S. Geol. Survey, PUMPELLY.

Kaolin in Blandford, Massachusetts, CROSBY.

Macfarlane's Railway Guide, CROSBY, HITCHCOCK.

Limestone at Norfolk, Connecticut, DANA.

Report—Atlantic coast Division, U. S. Geol. Survey, SHALER.

Studies of hornblende schist, HITCHCOCK.

Warren's geography, BREWER.

Archean and Algonkian—Continued.

Granitoid areas in lower Laurentian, HITCHCOCK. WILLIAMS, G. H.

New York to Georgia, Excursion in Northern Appalachians, WILLIAMS, G. H.

Metamorphic strata of southeastern New York, MERRILL, F. J. H.

Iron ores of the United States, HUNT T. S.

Iron ores of New York, SMOCK.

Clays near Morrisania, New York, MARTIN. MERRILL, F. J. H.

Archean axes of eastern North America, DANA.

Areas of continental progress in North America, DANA.

Analyses of intrusive diorite near Peekskill, New York, CHATARD.

Studies of Archean rocks, New Jersey, NASON.

Zircon rocks in highlands of New Jersey, NASON and FERRIER.

Scapolite rock, NASON.

Artesian wells, New Jersey, NASON.

Studies of Triassic rocks in New Jersey, NASON.

Serpentinous rocks, New York and Pennsylvania, MERRILL, G. P.

Serpentines of southeastern Pennsylvania, RAND.

Analyses of serpentines, CATLETT.

State line serpentines, Pennsylvania, CHESTER.

Gabbros of Delaware, CHESTER.

Non-feldspathic intrusives of Maryland, WILLIAMS, G. H.

Vicinity of Baltimore, WILLIAMS, G. H.

Analyses of rocks, Baltimore County, Maryland, CHATARD. WHITFIELD, J. E.

Analysis of dolomite from Cockeysville, Maryland, WHITFIELD, J. E.

Corundum in Patrick County, Virginia, GENTH.

Warren's geography, BREWER.

Macfarlane's Railway Guide, CHESTER. FONTAINE. HAMMOND. HITCHCOCK. HUNT. WHITE, I. C. McCUTCHEN. SAFFORD. CAMPBELL. SEELY. SMOCK. CHANCE. FONTAINE. WILLIAMS, G. H.

Western United States, Black Hills, VAN HISE.

Digitized by Google

Archean and Algonkian—Continued.
Areas of continental progress in North America, DANA.
Report—Montana division, U. S. Geol. Survey, PEALE.
Yellowstone Park, IDDINGS.
Crystalline rocks of Missouri, HAWORTH.
Building stones, Missouri, LADD.
Iron ores of the United States, HUNT, T. S.
Indian Territory and Red River, HILL.
Movements in Rocky Mountains, EMMONS.
Northwestern Colorado region, WHITE, C. A.
Central mineral region of Texas, COMSTOCK.
Texas-Pecos, Texas, STREERUWITZ.
Review of Texas geology, DUMBLE.
Displacements in the Grand Cañon, WALCOTT.
Warren's geography, BREWER.
Macfarlane's Railway Guide, ELDRIDGE. EMMONS. UPHAM. BROADHEAD. CHAMBERLIN. COOPER. DAWSON, G. M. EMMONS. HAGUE. PUMPELLY. WINCHELL, N. H.
Nomenclature, Use of term Laurentian, HITCHCOCK. JAMES. MARCOU.
Iron ores of the United States, HUNT, T. S.
Azoic system, AM. GEOLOGIST.

Archean and Algonkian—Continued.
Geology of Ontario, BELL.
Macfarlane's Railway Guide, LESLEY.

Arizona. Analyses of recent lavas, EAKINS.
Arizona's new bonanza, STORMS.
Building-stones, MERRILL, G. P.
Displacement in Grand Cañon, WALCOTT.
Macfarlane's Railway Guide, DUTTON.
Primary quartz in basalts, IDDINGS.
Warren's geography, BREWER.

Arkansas. Analysis of eruptive rock, EAKINS.
Building-stone, MERRILL, G. P.
Crowley's ridge, CALL.
Eastern Arkansas, CALL.
Macfarlane's Railway Guide, LOUGHRIDGE, OWEN.
Warren's geography, BREWER.

ASHBURNER, Charles A. Natural gas explorations in the eastern Ontario peninsula.
Engineering and Mining Jour., vol. 49, p. 313, 4°.
Geologic map, and a tabular section based mainly on well records.

Asia. Analysis of basalt, CHATARD.
Ascent of Japanese volcanoes, HOLLAND.

B.

BAILEY, G. E. [Geological notes on Dakota.]
Macfarlane's Geol. Railway Guide, 2d. edition, p. 256, ½ p.
At stations on part of Fremont, Elkhorn & Missouri Valley Railway.

BAILEY, L. W., Presidential address on the progress of geological investigation in New Brunswick.
Canada, Royal Soc., Trans., vol. 7, sec. IV, pp. 3–17.
A general review of New Brunswick geology and geologic history.

—— On some relations between the geology of eastern Maine and New Brunswick.
Canada, Royal Soc., Trans., vol. 7, sec. IV, pp. 57–68.
Abstract, Am. Geologist, vol. 6, p. 390, ½ p.
Discussion of age, relations, and distribution of the various formations, especially the Devonian and Silurian.

BAILEY, L. W.—Continued.
—— On the Acadian and St. Lawrence watershed.
Canadian Record of Science, vol. 3, pp. 398–413, 1889.
A summary account of its physiographic and geologic characteristics, comprising a description of formation from supposed pre-Cambrian to Devonian and a discussion of their age and relations.

—— and **McINNES**, Wm. Report on explorations and surveys in portions of northern New Brunswick and adjacent areas in Quebec and in Maine, U. S.
Canada, Geol. Survey, Reports, vol. 3, new series, part 2, report M, pp. 52, 1888.
Abstracts, ibid., part 1, report A, pp. 35–37; Am. Geologist, vol. 5, pp. 246–247, ¾ p.; Am. Jour. Sci., 3d series, vol. 39, p. 239, 4 lines.
The Silurian formation; its distribution, structure, stratigraphy, paleontology, equivalency, correlation and extent of its various members and evidences of internal unconformity.

Digitized by Google

BAILEY and McINNES—Continued.

—— —— [Account of explorations in northern New Brunswick.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 91-93. 1888.

Notes relating to the Silurian formation.

BARBOUR, Alfred E. On the contact of the Huronian and Laurentian rocks north of Lake Huron.

Am. Geologist, vol. 6, pp. 19-32.

Abstract, Am. Naturalist, vol. 24, p. 1072, 6 lines.

Characteristics, distribution, relations, and structure of the various rocks. With petrographic descriptions by A. C. Lawson, pp. 30-32.

BARBOUR, Erwin H., and **TORREY**, Joseph, jr. Notes on the microscopic structure of oolite, with analyses.

Am. Jour. Sci., 3d series, vol. 40, pp. 246-249.

From Iowa and Chester County, Pennsylvania.

BARTHOLOMEW, J. G. Geological sketch map of the world.

Scottish Geog. Magazine, vol. 6, plate 2.

Geology of North America from Marcou's maps.

BAYLEY, W. S. Notes on microscopical examinations of rocks from the Thunder Bay silver district.

Canada, Geol. Survey, Reports, vol. 3, new series, part 2, report H, pp. 115-122. 1888.

Entirely petrographic.

—— The origin of the soda-granite and quartz-keratophyre of Pigeon Point [Minnesota].

Am. Jour. Sci., 3d series, vol. 39, pp. 273-280.

Petrography, geologic relations, chemico-mineralogic history, and contact relations.

—— [Notice of relation of rocks at Pigeon Point, Minnesota.]

U. S. Geol. Survey, 8th Report, J. W. Powell, p. 139, ½ p. 1889.

Stated by R. D. Irving, report-Lake Superior division.

BECKER, George F. Report—U. S. Geological Survey. California division of Geology.

U. S. Geol. Survey, 8th Report, J. W. Powell, pp. 153-155, 1889.

Includes brief discussion of conditions affecting the texture of massive rocks.

—— Summary of the geology of the quicksilver deposits of the Pacific slope.

U. S. Geol. Survey, 8th Report, J. W. Powell, pp. 961-985, pls. LXII, LXIII, 1889.

Brief description of metamorphic and massive rocks and the geology of the various deposits; sketch of historical geology, and discussion of the origin and conditions of deposition of the ores.

BECKER, George F.—Continued.

—— Report.—California division.

U. S. Geol. Survey, 9th Report, J. W. Powell, pp. 100-102.

Includes some brief references to the geology of Almaden mine in Spain and to the discovery of Aucella in Tuolumne County, California, by H. W. Turner.

—— An elementary proof of the earth's rigidity.

Am. Jour. Sci., 3d series, vol. 39, pp. 336-352.

BELL, Robert. On glacial phenomena in Canada.

Geol. Soc. Am., Bull., vol. 1, pp. 287-310.

Abstract, Am. Naturalist, vol. 24, pp. 207-208, ½ p.; p. 771, 5 lines.

General review of glacial history and discussion of nature of certain glacial features.

—— The origin of gneiss and some other primitive rocks [abstract].

Am. Assoc. Adv. Science, Proc., vol. 38, pp. 227-231.

General discussion, with incidental references to nature of certain crystalline rocks in various parts of Canada.

—— [Summary of exploration in 1887 about the Lakes Temiscaming and Abbittibbi, the Montreal River, and the upper waters of the Ottawa.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 22-27, 1888.

Brief reference to general geologic features, mainly concerning characteristics and distribution of crystalline rocks and extent of the Silurian limestones.

—— [Summary of observations between the Montreal River and the northern shores of Lake Huron.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 77-80, 1888.

Includes brief reference to the distribution and relations of the Huronian and Laurentian rocks.

—— The geology of Ontario with special reference to economic minerals. Report of Royal Commission on the mineral resources of Ontario, pp. 57, Toronto, 1889.

Abstracts, Am. Geologist, vol. 5, pp. 238-240; Engineering and Mining Jour., vol. 49, p. 468, 1¼ col., 4°.

Brief descriptions of the characteristics, distribution, general relations, and economic resources of the Archean, Cambrian, Silurian, Devonian, and post-Tertiary formations.

Bermudas. Origin of present outline of the Bermudas, FEWKES.

Digitized by Google

SHOP, I. P. A new locality of Lower Silurian fossils in the limestones of Columbia County, New York.

Am. Jour. Sci., 3d series, vol. 31, pp. 69–70, ½ p.

Includes references to the geologic relations of the limestones and their correlation with other belts in the same county.

LTON, H. Carrington. Scientific ittings on the Nile and in the desert.

New York Acad. Sci., Trans., vol. 9, pp. 110–126.

Includes notes on geology.

ONNEY, T. C.] [Remarks on significance of certain features of the Great ake region of America bearing on eir history.]

Geol. Soc., Quart. Jour., vol. 46, p. 532, ¼ p.

Discussion of paper by J. W. Spencer "On the origin of the basins of the Great Lakes of America."

ston Society of Natural History, roceedings, vol. 24, pp. 355 to end.

Reply to Selwyn on classification for Quebec, MARCOU.

Geographic development of northern New Jersey, DAVIS and WOOD.

Record of well at Nampa, Idaho, KURTZ.

Age of beds in Boisé River region, Idaho, EMMONS.

Growth, culmination, and departure of the ice sheets, UPHAM.

Changes of climate indicated by interglacial beds, LEVERETT.

Note on glacial climate, SHALER.

Exceptional nature of climate of glacial period, UPHAM.

Evidence in the till on the glacial climate, CROSBY.

Saliferous deposits evidence of former climatal conditions, SHALER.

Glacial studies bearing on the antiquity of man, LEVERETT.

Sanborn bowlder, SAVILLE.

——— **vol. 25,** pp. 1–80.

Geological history of Boston basin, CROSBY.

WER, Stephen. San Nicolas Island.

California, Ninth Report of Mineralogist, pp. 57–61.

Includes a brief account of its geology.

WMAN, Amos. Report on the geology of the mining district of Caribou, British Columbia.

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report C, pp. 49, maps, 1888.

BOWMAN, Amos. Report—Continued.

Descriptions of Archean, lower and upper Paleozoic, Cretaceous, Miocene, Pliocene (?), and Pleistocene formations, and their structural relations, especially in connection with the mineral deposits.

—— [Explorations on the seaboard of British Columbia.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report A, pp. 66–69, 1888.

Includes brief references to the Tertiary and Cretaceous formations and their coals and lignites.

BOYD, C. R., Middlesborough, Ky.

Engineering and Mining Jour., vol. 49, pp. 171–173, 4°.

Includes a section showing coal beds and strata from upper Silurian fossil ore bed to Carboniferous.

BRAINERD, Ezra, and SEELY, Henry M. The Calciferous formations in the Champlain Valley.

Geol. Soc. Am., Bull., vol. 1, pp. 501–511.

Am. Mus. Nat. Hist., Bull., vol. 3, pp. 1–23

Abstracts, Am. Geologist, vol. 5, p. 120, 7 lines; Am. Jour. Sci., 3d series, vol. 39, pp. 235–238; Am. Naturalist, vol. 24, p. 955, 6 lines.

Distribution, stratigraphy, detailed description of sections and correlation of Fort Cassin strata and members of Phillipsburgh series.

BRANNER, John C. The Æolian sandstones of Fernando de Noronha.

Am. Jour. Sci., 3d series, vol. 39, pp. 247–257.

Characteristics, distribution, structure, erosion, chemical composition, and history.

—— The training of a geologist.

Am. Geologist, vol. 5, pp. 147–160.

—— The Cretaceous and Tertiary geology of the Sergipe-Alagôas basin of Brazil.

Am. Phil. Soc., Trans., vol. 16, new series, pp. 369–434, pls. 1–5.

Abstract, Am. Geologist, vol. 6, pp. 121–122, ¾ p.

Description of characteristics and relations at various localities of Mesozoic, Tertiary and post-Tertiary formations; discussion of stratigraphic relations and history of deposition, etc.; references to other Mesozoic regions in Brazil and to relations to Paleozoic and Archean formations. Bibliography.

—— The relations of the State and National Geological Surveys to each other and to the geologists of the country.

Am. Geologist, vol. 6, pp. 295–309.

Science, vol. 16, pp. 120–123. 4°.

BREWER, William H. Warren's New Physical Geography, pp. 144, 4°. Philadelphia [1890].

Digitized by Google

BREWER, William H.—Continued.
Includes some general statements in regard to the principles of geologic science and the geologic history of North America, and a colored geologic map of the United States on which some new features are introduced, notably the representation of glacial and aqueous Quaternary deposits.

[BRITTON, N. L.] [Clay outlier near Monmouth Junction, New Jersey.]
New York Acad. Sci., Trans., vol. 9, p. 83, 2 lines.
Reference to its age.

BROADHEAD, G. C. Missouri.
Macfarlane's Geol. Railway Guide, 2d edition, pp. 267–273.
Geological notes for railway stations.

BRYSON, John. Preglacial channels at the falls of the Ohio.
Am. Geologist, vol. 5, pp. 186–188.
Description of their course and topography and reference to their history.

—— The Wetwoods.
Am. Geologist, vol. 6, pp. 254–255.
Description of an imperfectly drained region in central Kentucky and discussion of its history.

C.

California, Analyses of clays from Owen's Lake, CHATARD.
Analyses of lavas from Lassen Peak, HILLEBRAND. RIGGS.
Analyses of lavas from Shasta County, RIGGS.
Analyses of volcanic rocks, CHATARD. WHITFIELD, J. E. EAKINS. HILLEBRAND.
Auriferous gravels, HAMMOND.
Building-stone, MERRILL, G. P.
Cements, IRELAND.
Clays, JOHNSON, W. D.
Cretaceous of northern California, DILLER.
Fossils as indicators of mineral products, COOPER.
Geology of Channel Islands, YATES.
Geology of Lassen Peak district, DILLER.
Geology of quicksilver deposits, BECKER.
Glass, DE GROOT.
Islands of Santa Barbara Channel.
Los Angeles County, PRESTON.
Macfarlane's Railway Guide, COOPER. TURNER.
Mines of Calico County, STORMS.
Natural soda, CHATARD.
Paleontology of northwest coast, DALL.
Protozoötites, FRIEDERICH.
Quaternary history of Mono Valley, RUSSELL.
Report—California division, U. S. Geol. Survey, BECKER.
Report—division of volcanic geology, U. S. Geol. Survey, DUTTON.
San Bernadino County, CROSSMAN.

California—Continued.
San Diego County, GOODYEAR.
Sandstone dikes, DILLER.
San Nicolas Island, BOWER.
Santa Clara County, WEBER.
Santa Cruz Island, GOODYEAR.
Spherulites from near Hot Springs, RUTLEY.
Warren's geography, BREWER.

California Academy of Sciences, Proceedings, vol. 2.
Petrographical notes from Baja California, Mexico, LINDGREN.

California, State Mineralogist, ninth annual report.
Santa Clara County, WEBER.
San Nicholas Island, BOWER.
Auriferous gravels, HAMMOND.
San Diego County, GOODYEAR.
Santa Cruz Island, GOODYEAR.
Notes on Channel Islands, YATES.
Los Angeles County, PRESTON.
San Bernardino County, CROSSMAN.
Fossils as indicators of mineral products, COOPER.
Clays, JOHNSON, W. D.
Cements, IRELAND.
Glass, DE GROOT.

CALL, R. Ellsworth. The geology of Crowley's Ridge, Arkansas. [Abstract.]
Iowa Acad. Sci., Proc., 1887–89, pp. 52–53.
Brief description of Eocene and Quaternary formations.

—— On the geology of eastern Arkansas. [Abstract.]
Iowa Acad. Sci., Proc., 1887, 1889, pp. 85–90.
General description of the formations, topographic characteristics and soils, and sketch of geologic history of the region.

Digitized by Google

Cambrian.

Canada, report on Quebec, ELLS.
Review of Ells's report on Quebec, WALCOTT.
Acadian and St. Lawrence watershed, BAILEY.
Stratigraphy of "Quebec Group," ELLS.
Geological classification for Quebec, MARCOU.
Geology of Quebec city, ELLS. SELWYN.
Quebec and Taconic, AM. GEOLOGIST.
Quebec group of Logan, DAWSON, J. W.
Geology of Ontario, BELL.
New Brunswick, BAILEY. BAILEY and MCINNES.
Lower and middle Taconic, MARCOU.
Serpentines of Canada, GIROUX.
Organisms in Acadia, MATTHEW.
Pre-Paleozoic surface in Canada, LAWSON.
Macfarlane's Railway Guide, DAWSON, G. M.
Warren's geography, BREWER.

New York and New England, Report, paleozoic division of paleontology, U. S. Geol. Survey, WALCOTT.
Calciferous in Champlain Valley, BRAINARD and SEELY.
Report.—Division of Archean geology, U. S. Geol. Survey, PUMPELLY.
Middle Cambrian at Stissing, New York, DWIGHT.
Report,—Division of Paleozoic invertebrates, U. S. Geol. Survey, WALCOTT.
Mount Desert Island, SHALER.
Studies of hornblende schist, HITCHCOCK.
Cape Ann, SHALER.
Essex County, Massachusetts, SEARS.
Granites in Massachusetts, EMERSON.
Ottrellite and Ilmenite schists, WOLFF.
History of Boston Basin, CROSBY.
Iron ores, HUNT, T. S.
Warren's geography, BREWER.
Macfarlane's Railway Guide, DANA. DWIGHT. FORD. CROSBY. HUNT, T. S. HITCHCOCK.

Pennsylvania–Virginia, Making of Pennsylvania, CLAYPOLE.
Casts of Scolithus, WANNER.
Iron ores, HUNT, T. S.

Cambrian—Continued.

Pennsylvania–Virginia—Continued.
Warren's geography, BREWER.
Macfarlane's Railway Guide, CAMPBELL. FONTAINE. LESLEY.

Illinois, Artesian waters from the drift, ROLFE.

Great Lake Region, Menominee and Marquette regions, IRVING.
Macfarlane's Railway Guide, CHAMBERLIN. WINCHELL, A.

Western United States, Review of Texas geology, DUMBLE.
Central mineral region of Texas, COMSTOCK.
Central Texas, TARR.
Extinct volcanoes in Colorado, LAKES.
Displacements in Grand Cañon, WALCOTT.
Movements in Rocky Mountains, EMMONS.
Northwestern Colorado region, WHITE, C. A.
Report, Montana division, U. S. Geol. Survey, PEALE.
Black Hills, VAN HISE.
Warren's geography, BREWER.
Macfarlane's Railway Guide, DAWSON, G. M. EMMONS. HAGUE. MCGEE. PUMPELLY. PUTNAM. WINCHELL, N. H.

Nomenclature, Geological classification for Quebec, MARCOU.
History of Quebec group, HUNT.
Lower and middle Taconic, MARCOU.
North American Geology by Miller, DANA.
Quebec and Taconic, AM. GEOLOGIST.
Quebec group of Logan, DAWSON, J. W.
Sedgwick and Murchison; Cambrian and Silurian, DANA.
The Cambrian system, DWIGHT.
Iron ores of the United States, HUNT, T. S.

[CAMPBELL, J. L. and H. D.] Georgia Pacific Railway.
Macfarlane's Geol. Railway Guide, 2d edition, pp. 383–385.
Geological notes for stations in Alabama and Georgia.

[—— ——] [Virginia in part.]
Macfarlane's Geol. Railway Guide, 2d edition, pp. 359–362.
Geological notes for railway stations, mainly in the western part of the State.

Digitized by Google

CANADA. Acadian and St. Lawrence water shed, BAILEY.
Ancient shores in region of the Great Lakes, SPENCER.
Areas of continental progress, DANA.
Archean of central Canada, LAWSON.
Archean axes of eastern North America, DANA.
Archean northwest of Lake Superior, LAWSON.
Between Montreal River and Lake Huron, BELL.
Big Bend of the Columbia, COLEMAN.
Calciferous in Champlain Valley, BRAINARD and SEELY.
Calciferous formation, WALCOTT.
Cambrian organisms in Acadia, MATTHEW.
Caribou district, British Columbia, BRANNER.
Copper at Thunder Bay, LAWSON.
Chalk from Niobrara, DAWSON, G. M.
Cretaceous of Manitoba, TYRRELL.
Deformation of Iroquois beach, SPENCER.
Duck and Riding Mountains, TYRRELL.
Eastern townships of Quebec, ADAMS.
Eastern Maine and New Brunswick, BAILEY.
Eozoon in Laurentian at St. John, MATTHEW.
Erosion in valley of the Don, HARVEY.
Eruptives of Lake Huron region, FAIRBANKS.
Excursion in northern Appalachians, WILLIAMS, G. H.
Expedition down Anderson River, DAWSON, G. M.
Exploration in Yukon district, DAWSON, G. M.
Fossils from Manitoba, WHITEAVES.
Fossil plants from Mackenzie and Bow Rivers, DAWSON, J. W.
Fossil plants from British Columbia, DAWSON, J. W.
Fossil sponges from Little Metis, DAWSON, J. W.
Gas in eastern Ontario, ASHBURNER.
Geology of Ontario, BELL.
Geology of Quebec City, AMI. ELLS. SELWYN.
Geology of the northwest of Lake Superior, HARVEY.

CANADA—Continued.
Geological progress, ELLS.
Geological classification for Quebec, MARCOU.
Glacial features, Yukon and Mackenzie Rivers, MCCONNELL.
Glacial phenomena, BELL.
Glaciation of eastern Canada, CHALMERS.
Glaciation of northern Cordillera, DAWSON, G. M.
Gold-bearing rocks in Halifax County, FARIBAULT.
Gravels of Ontario, SPENCER.
History of Quebec group, HUNT.
History of Niagara River, GILBERT.
Hudson Bay, LOW.
Hunter Island and Seine River region, SMITH, W. H.
Huronian-Laurentian contact north of Lake Huron, BARLOW.
Huronian and Laurentian north of Lake Huron, LAWSON.
Iroquois beach, DAVIS. SPENCER.
Iron ores of the United States, HUNT, T. S.
James Bay region, LOW.
Kamanistiquia silver belt, WOOD.
Lake Tamiscaming and Montreal River region, BELL.
Lake St. John County, CHAMBERS.
Laramie group, TYRRELL.
Limits of glaciation in the Northwest, CHAMBERLIN.
Lithology of rocks from Yukon district, ADAMS.
Lower and Middle Taconic, MARCOU.
Lower Laird River, MCCONNELL.
Lower Helderberg of St. Helen's Island, DEEKS.
Maquoketa shales, JAMES.
Macfarlane's Railway Guide, DAWSON, G. M.
Microscopic examination of rocks from Thunder Bay silver district, BAYLEY.
Mineral wealth of British Columbia, DAWSON, G. M.
Mines on Lake Superior, INGALL.
Mistassini region, LOW.
Montcalm and Joliette Counties, ADAMS.
Moraine of recession in Ontario, WRIGHT.
Movements in Rocky Mountains, EMMONS.

Digitized by Google

CANADA—Continued.

Northeastern extension of the Iroquois beach, SPENCER.
North side of the St. Lawrence above Quebec, LAFLAMME.
Northwestern Manitoba, TYRRELL.
Northern New Brunswick, BAILEY and McINNES.
Notes on Cretaceous of British Columbia, DAWSON, G. M.
Nova Scotia Carboniferous conglomerate, GILPIN.
Origin of the basins of the Great Lakes, SPENCER. BONNEY. HINDS. SEELY.
Origin of gneiss, BELL.
Observations on certain rocks, WINCHELL, A.
Petrography of certain dikes of Rainy Lake region, LAWSON and SHUTT.
Pictou and Colchester counties, Nova Scotia, FLETCHER.
Pleistocene flora of Canada, DAWSON, J. W.
Pleistocene submergence, SPENCER.
Post-Tertiary deposits of Manitoba, TYRRELL.
Pot holes north of Lake Superior, MCKELLAR.
Pre-Paleozoic surface of Archean, LAWSON.
Progress of investigation in New Brunswick, BAILEY.
Quebec group of Logan, DAWSON, J. W.
Quebec and Taconic, AM. GEOLOGIST.
Reply to Selwyn on geological classification for Quebec, MARCOU.
Report on Rainy Lake region, LAWSON.
Report on Quebec, ELLS.
Results of Archean studies, WINCHELL, A.
Review of Ells's report on Quebec, WALCOTT.
Rocky Mountain protaxis, DANA.
Seaboard British Columbia, BOWMAN.
Southern interior British Columbia, DAWSON, G. M.
Southern invertebrates on shores of Acadia, GANNONG.
Sponges in rocks at St. John, MATTHEW.

CANADA—Continued.

Stratigraphy of "Quebec Group," ELLS.
Summary reports of geological surveys for 1887, 1888, SELWYN.
Surface geology of New Brunswick, CHALMERS.
St. Lawrence Valley, ELLS.
Tracks in Animikie rocks, SELWYN.
Triassic traps of Nova Scotia, MARSTERS.
Warren's Geography, BREWER.

Canada, Geological and Natural History Survey, Annual Report, new series, vol. 3, parts 1 and 2, 1887–88.

Summary reports, SELWYN.
Yukon district, DAWSON, G. M.
Lithology, Yukon collections, ADAMS.
Caribou mining district, BOWMAN.
Duck and Riding Mountains, TYRRELL.
Rainy Lake region, LAWSON.
Mines of Lake Superior, INGALL.
Rocks from Thunder Bay district, BAYLEY.
James Bay country, LOW.
Portion of Province of Quebec, ELLS.
Northern New Brunswick, BAILEY and McINNES.
Surface geology northeastern New Brunswick, CHALMERS.
Mineral wealth of British Columbia, DAWSON, G. M.

Canada, Report of Royal Commission on the mineral resources of Ontario,
Geology of Ontario, BELL.

Canada, Royal Society, Transactions, vol. 7.

Progress of investigation in New Brunswick, BAILEY.
Sponges from Siluro-Cambrian at Little Metis, DAWSON, J. W.
Eastern Maine and New Brunswick, BAILEY.
Plants from Mackenzie and Bow Rivers, DAWSON, J. W.
Fossils from Cambro-Silurian rocks of Manitoba, WHITEAVES.
Geology of Big Bend of the Columbia, COLEMAN.
The Iroquois beach, SPENCER.
Cambrian organisms in Acadia, MATTHEW.

Digitized by Google

Canadian Institute, Proceedings, vol. 7.

Geology of northwest Lake Superior, HARVEY.

Kaministiquia silver belt, WOOD.

Canadian Record of Science, vol. 3, Nos. 7, 8.

Cambrian organisms in Acadia, MATTHEW.

Lake St. John country, CHAMBERS.

Acadian and St. Lawrence watershed, BAILEY.

How is the Cambrian divided? MATTHEW.

——— vol. 4.

Expedition down Anderson River, DAWSON, G. M.

Lower Helderberg of St. Helen's Island, DEEKS.

Quebec group of Logan, DAWSON, J. W.

CANNON, George L., jr. [Remains of Dinosaurs and Stegosaurs in the Laramie of Montana.]

Colorado Sci. Soc., Proc.. vol. 3, p. 190, ½ p.
Remarks on the paleontologic evidence as to the age of the containing beds.

——— [Notes on the formations in eastern Colorado.]

Colorado Sci. Soc., Proc., vol. 3, pp. 215–216, ½ p.
Reference to the thickness of the loess, presence of extensive superficial eolian deposits, and exposures of supposed Pliocene beds lying on Fox Hills sediments.

CANTWELL, J. C. [Letter on the ice cliffs on Kowak River, Alaska.]

Am. Geologist, vol. 6, pp. 51–52.
Brief description of their structure.

Carboniferous (including Permian).

Canada, Caribou district, British Columbia, BOWMAN.

Nova Scotia Carboniferous conglomerate, GILPIN.

Triassic traps of Nova Scotia, MARSTERS.

Archean axes of eastern North America, DANA.

Serpentines, GIROUX.

Pictou and Colchester Counties, Nova Scotia, FLETCHER.

Progress in New Brunswick, BAILEY.

Yukon district, DAWSON, G. M.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, DAWSON, G. M.

Carboniferous—Continued:

New England, History of Boston, Basin CROSBY.

Essex County, Massachusetts, SEARS.

Ottretite and ilmenite schist, WOLFF.

Areas of continental progress, DANA.

Macfarlane's Railway Guide, CROSBY. HITCHCOCK.

Warren's Geography, BREWER.

Archean axes, DANA.

Appalachians to the Mississippi, locality numbers, HALL.

Paleozoic fishes, NEWBERRY.

Report on oil and gas, CARLL.

Report on New Boston and Morea coal lands, LYMAN.

Fractured strata in Bedford County, Pennsylvania, STEVENSON.

Making of Pennsylvania, CLAYPOLE.

Umbral limestone in Lycoming County, Pennsylvania, MEYER.

Waverly group, COOPER, W. F.

Analysis of sandstone from Portsmouth, Ohio, CHATARD.

Analysis of sandstone from Berea, Ohio, EAKINS.

Analysis of sandstone from Buena Vista, Ohio, CLARKE.

Sylvania sand in Ohio, NEFF.

Geological survey of Ohio, report, ORTON.

Oil field of Barren County, Kentucky, FISCHER.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, PROCTOR. SAFFORD. COLLETT. WINCHELL, A. LESLEY. LEWIS. ORTON. ROGERS. PARSONS. WHITE, I. C. CAMPBELL. SMITH and GESNER. MCCUTCHEN. FONTAINE.

Analysis of metamorphic rock from Marion, Kentucky, EAKINS.

Middleborough, BOYD.

Central basin of Tennessee, KENNEDY.

Iowa, Missouri, Kansas, Keokuk beds, GORDON.

Deep well at Le Mars, Iowa, TODD.

Folding in southwestern Iowa, TODD.

Brecciated character of St. Louis limestone, GORDON.

Crinoids from Burlington limestone, ROWLEY.

Digitized by Google

Carboniferous—Continued.
Iowa, Missouri, Kansas—Continued.
Coal beds of Lafayette County, Missouri, WINSLOW.
Introduction, Southwestern Kansas, MCGEE.
Southwestern Kansas, HAY.
Analysis of Silverdale limestone, CATLETT.
Artesian wells in Kansas, HAY.
Kansas salt mines, HAY.
Permo-Carboniferous of Kansas, WOOSTER.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, BROADHEAD. MCGEE. ST. JOHN.
Arkansas to Mexico, eastern Arkansas, CALL.
Areas of continental progress, DANA.
Indian Territory and Red River, HILL.
Coal of Indian Territory, CHANCE.
Central Texas, TARR.
Coal field of Colorado River, TARR.
Trans-Pecos Texas, STREERUWITZ.
Review of Texas geology, DUMBLE.
Geographic features of Texas, HILL.
Permian of Texas, CUMMINS.
Central mineral region of Texas, COMSTOCK.
Central coal field of Texas, CUMMINS.
Concho country, Texas, CUMMINS and LERCH.
Coal fields of Texas, WEITZEL.
Cretaceous of northern Mexico, WHITE, C. A.
Baja California, LINDGREN.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, FRAZER. LOUGHRIDGE.
Rocky Mountain region, analysis of limestone from Montana, CATLETT.
Report—Montana division U. S. Geol. Survey, PEALE.
Report—Division of paleobotany, U. S. Geol. Survey, WARD, L. F.
Movements in Rocky Mountains, EMMONS.
Northwestern Colorado region, WHITE, C. A.
Extinct volcanoes in Colorado, LAKES.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, DAVIS. DAWSON, G. M. EMMONS. GILBERT. HAGUE. PUMPELLY, PUTNAM.
Arizona, displacements in Grand Cañon, WALCOTT.
Macfarlane's Railway Guide, DUTTON.
Warren's Geography, BREWER.
Central America, Nicaragua, CRAWFORD.
California, Lassen Peak district, DILLER.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, COOPER.

CARLL, John F. Pennsylvania Geological Survey, Seventh Report, on the oil and gas fields of western Pennsylvania for 1887–'88 (following the annual reports of 1885 and 1886), with additional unpublished well records, pp. viii, 356, 6 maps, sections, and charts.

Includes an extended account of the stratigraphy, structure, and distribution of the oil and gas and associated formations in Pennsylvania and adjoining States.

CASTILLO, Antonio del. Bosquejo de una carta geológica de la República Mexicana, formada por disposicion del Secretario de Fomento, Gral. Carlos Pocheco, por una comision especial. Escale de 3,000,000. 1889. [41 × 29 inches.]

Showing distribution of the various Mesozoic and Cenozoic sediments and volcanic and metamorphic rocks over about four-fifths of its area.

CATLETT, C. [Carboniferous limestones from Montana, analyses.]

U. S. Geol. Survey, Bull. No. 60, p. 154, ½ p.

—— White earth from Talladega, Alabama [analyses].

U. S. Geol. Survey, Bull. No. 60, p. 158, ½ p.

—— [Trenton limestones from Ohio and Indiana, analyses.]

U. S. Geol. Survey, Bull. No. 60, pp. 161–162, ½ p.

—— Serpentine and its associates, [analyses].

U. S. Geol. Survey, Bull. No. 64, pp. 43–44. Moriah and New York, New York; Montville, New Jersey, and eastern Pennsylvania.

—— Limestones from Silverdale, Kansas [analyses].

U. S. Geol. Survey, Bull. No. 64, p. 46, ½ p.

—— Clays [analyses].

U. S. Geol. Survey, Bull. No. 64, pp. 51, ½ p. Talladega, Alabama; Richfield Springs, New York, and Northumberland County, Pennsylvania.

Digitized by Google

Central America. About the Nicaragua footprints, FLINT.

Geologic survey of Nicaragua, CRAWFORD.

Letter on geology of Nicaragua, CRAWFORD.

Pleistocene submergence of the Isthmus of Panama, UPHAM.

CHALMERS, R. Report of the surface geology of northeastern New Brunswick to accompany quarter sheet maps 2 NE. and 6 SW.

Canada, Geol. Survey, Reports, vol. 3, new series, part 2, report N, pp. 33, 2 maps, 1888.

Abstracts, Ibid., part 1, report A, pp. 37–38. ¾ p; Am. Geologist, vol. 5, pp. 247, ½ p.

Descriptions of the various surface deposits, glacial phenomena, terraces, and soils.

—— [Account of examinations of surface deposits of southern New Brunswick.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 94–96, 1888.

Glacial deposits and striæ, basins of extinct post-Tertiary lakes and stratified post-Tertiary deposits.

—— Glaciation of eastern Canada.

Am. Geologist, vol. 6, pp. 240–244.

Abstract by author. Original paper in Canadian Record of Science, vol. 3, pp. 319–333, 1889.

—— The glaciation of the Cordillera and the Laurentide.

Am. Geologist, vol. 6, pp. 324–325.

Discusses extent, distribution, and conditions of development of Canadian glacial systems.

CHAMBERLIN, T. C. Report—division of glacial geology.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 141–144, 1889.

An account of the various investigations, including a brief abstract of certain results obtained by R. D. Salisbury, in northern Indiana and Illinois.

—— Introduction. The glacial boundary in western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois by G. F. Wright.

U. S. Geol. Survey, Bull. No. 58, pp. 13–38.

General remarks concerning the phenomena and history of the southern margin of the drift, account of observations on terraces of the upper Ohio River, and discussion of the age and relations and history of these terraces, of the conditions attending the presence of a glacial ice dam in the Ohio River, and of the discrimination of fluvial and lacustral terraces in general.

CHAMBERLIN, T. C.—Continued.

—— Bowlder belts distinguished from bowlder trains; their origin and significance.

Geol. Am. Soc., Bull., vol. 1, pp. 27–28, 30–31.

Discussed by A. Winchell, G. F. Wright, and C. H. Hitchcock, pp. 29–31.

—— [Remarks on the extent of Pleistocene glaciers and the cause of the glacial epoch.]

Geol. Soc. Am., Bull., vol. 1, pp. 154–155, ¾ p.

In discussion of paper by I. C. Russell entitled "Notes on the surface geology of Alaska."

—— [Remarks on the outlet of Lake Agassiz and the limitation of Pleistocene glaciation in northwestern North America.]

Geol. Soc. Am., Bull., vol. 1, pp. 407–408.

—— Some additional evidences bearing on the interval between the glacial epochs.

Geol. Soc. Am., Bull., vol. 1, pp. 469–474, 475–476, 478–479.

Abstracts, Am. Geologist, vol. 5, p. 118, ½ p.; Am. Naturalist, vol. 24, p. 771, 6 lines.

Discusses evidence of lower Mississippi, Ohio, Susquehanna, and Delaware Rivers. Discussed by W J McGee, J. R. Proctor, F. J. H. Merrill, and I. C. White, pp. 474–479.

—— North and South Dakota.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 253–256.

Geologic notes for railway stations.

—— Wisconsin.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 223–232.

Geologic notes for railway stations.

—— [Notes on glacial features at points in New York, Illinois, and Dakota.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 131, 134, 138, 221, 253–256.

CHAMBERS, E. T. Notes on the Lake St. John country.

Canadian Record of Science, vol. 3, pp. 388–394. 1889.

Contains brief references to characteristics of the crystalline rocks and to some occurrences of Trenton fossils and Pleistocene deposits.

CHANCE, H. M. Coal Measures of the Indian Territory.

Am. Geologist, vol. 6, pp. 238–240.

General account of thickness, extent, stratigraphic components, and age.

—— [Geological notes on Mexican Central Railroad.]

Macfarlane's Geol. Railway Guide, 2d edition, p. 418, ½ p.

Digitized by Google

CHANCE, H. M.—Continued.

—— North Carolina.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 365–368.

Chapter by W. C. Kerr of first edition, enlarged and revised by H. M. Chance.

CHARLTON, Thomas. Notes on the occurrence of charcoal at a depth of 630 feet in the Silver Cliff mining district, Custer County, Colorado.

Engineering and Mining Jour., vol. 49, p. 332, ½ col. 4°.

Geologic relations. Reference to age of the rhyolites.

CHATARD, T. M. Two [eruptive] rocks from Montana. [Analyses.]

U. S. Geol. Survey, Bull., No. 55, pp. 83–84, ⅔ p., 1889.

From Cottonwood Creek and east of Ft. Ellis.

—— [Volcanic] rocks from California. [Analyses.]

U. S. Geol. Survey, Bull., No. 55, p. 84, ½ p., 1889.

—— Two clays from shore of Owen's Lake, California. [Analyses.]

U. S. Geol. Survey, Bull., No. 55, p. 89, ½ p., 1889.

—— Natural soda; its occurrence and utilization.

U. S. Geol. Survey, Bull., No. 60, pp. 27–101.

Includes description of deposits in various parts of the world, especially in California, Nevada, and Oregon.

—— Brick clay from New Ulm, Minnesota. [Analyses.]

U. S. Geol. Survey, Bull., No. 60, p. 151, ½ p.

—— Rocks collected by R. D. Irving. [Iron carbonates and limestones, Penokee-Gogebic region. Analyses.]

U. S. Geol. Survey, Bull., No. 60, pp. 150–151.

—— Inclusion in diorite from Cruger's station, near Peekskill, New York. [Analysis.]

U. S. Geol. Survey, Bull., No. 60, p. 158, ½ p.

—— Basalt Island of Mytilene, Asia Minor, [Analysis.]

U. S. Geol. Survey, Bull., No. 60, p. 158. ½ p.

—— Rocks from Baltimore County, Maryland. [Analyses.]

U. S. Geol. Survey, Bull., No. 64, p. 43, ½ p.

Pyroxenite and diallage-bronzite rocks.

—— Sandstones from near Portsmouth, Ohio. [Analysis.]

U. S. Geol. Survey, Bull., No. 64, p. 45, ½ p.

—— Diabase, Penokee-Gogebic range, Michigan. [Analyses.]

U. S. Geol. Survey, Bull., No. 64, p. 47, ½ p.

CHATARD, T. M. and **BAKINS**, L. G. Rocks from Montana. [Analyses.]

U. S. Geol. Survey, Bull., No. 60, pp. 152–154.

CHESTER, Frederick D. The gabbros and associated rocks in Delaware.

U. S. Geol. Survey, Bull. 59, pp. 45, map.

Petrographic descriptions, account of structural relations, distribution, discussion of origin, and genetic relations. Colored geologic map of northern Delaware.

—— The state line serpentine and associated rocks.

Pennsylvania Geol. Survey, Report for 1887, pp. 93–165.

Abstract, Am. Naturalist, vol. 23, p. 812, ½ p. 1889.

Petrography of the serpentines and associated rocks and brief discussion of their history and structural relations.

—— Delaware, Eastern shore of Maryland and Virginia.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 329–331.

Geological notes for railway stations and their vicinity,

Cincinnati Society of Natural History, Journal, vol. 13.

Cave in Clinton formation of Ohio, JAMES.

CLARK, William B. On the Tertiary deposits of the Cape Fear River region.

Geol. Soc. Am., Bull., vol. 1, pp. 537–540.

Abstracts, Am. Geologist, vol. 5, p. 119, ½ p.; Am. Naturalist, vol. 24, p. 289, ½ p.

Relations, history, and fauna of Cretaceous Eocene and Miocene.

—— Third annual geological expedition into southern Maryland and Virginia.

Johns Hopkins Univ., Circulars, vol. 9, No. 81, pp. 69–71, 4°.

Brief summary of formations of the coastal plain and notes on the exposures at Fort Washington, Glymont, Acquia Creek, Pope's Creek, Nomini Cliffs, St. Mary's River, and Cornfield Harbor on the Potomac, Yorktown on the York, and Grove wharf on the James.

—— The geological features of Gay Head, Massachusetts.

Johns Hopkins Univ., Circulars, vol. 10, No. 84, p. 28, 1¼ col., 4°.

Includes brief general references to the Cretaceous, Tertiary, and Pleistocene formations and structure.

CLARKE, F. W. Triassic sandstone from Maryland. [Analysis.]

U. S. Geol. Survey, Bull., No. 55, p. 80, ½ p., 1889.

From near Hancock.

Digitized by Google

CLARKE, F. W.—Continued.

—— Clay . . . from Martha's Vineyard, Massachusetts, parital analysis.

U. S. Geol. Survey, Bull., No. 55, pp. 89–90, ½ p. 1889.

—— [Trenton limestone from Ohio and Indiana, analyses.]

U. S. Geol. Survey, Bull., No. 60, pp. 160, 162, ½ p.

—— Coquina and coral rocks. [From Florida analyses.]

U. S. Geol. Survey, Bull., No. 60, p. 162, ½ p.

—— Sandstone from Buena Vista, Ohio. [Analysis.]

U. S. Geol. Survey, Bull., No. 64, p. 45, ½ p.

—— and **RIGGS**, R. B. [Limestone from Ohio. Analyses.]

U. S. Geol. Survey, Bull., No. 60, p. 160, ½ p. Trenton limestones and Utica shales.

CLARKE, J. M. Report on the bones of Mastodon or Elephas found associated with charcoal and pottery at Attica, Wyoming County, New York.

New York State Museum, Forty-First Report, pp. 388–390, pls. 1888.
Description and section of containing beds.

—— The Hercynian question. A brief review of its development and present status, with a few remarks upon its relation to the current classification of American faunas.

New York State Museum, Forty-Second Report, pp. 408–437. 1889.
Discussed by C. D. Walcott, Am. Jour. Sci., 3d series, vol. 39, pp. 155–156.
Review of the faunal relations of the Upper Silurian to the Lower Devonian.

CLAYPOLE, E. W. Illustration of the "level of no strain" in the crust of the earth.

Am. Geologist, vol. 5, pp. 83–88.
Discussion of its position.

—— The making of Pennsylvania.

Am. Geologist, vol. 5, pp. 225–234.
Sketch of the Paleozoic geologic history.

—— The reality of a level of no strain in the crust of the earth. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, p. 232, ½ p.

CLAYPOLE, K. B. Recent glacial work in Europe.

Popular Science Monthly, vol. 37, pp. 103–106.

CLIFFORD, W. Additional notes no Richmond coal field, Virginia, in reply to criticisms.

Manchester Geol. Soc., Trans., vol. 20, pp. 247–256, 1889.
Discussion of structure, stratigraphy, and relation of eruptives, together with quotations from various observers.

COLEMAN, A. P. Notes on the geography and geology of the Big Bend of the Columbia.

Canada, Roy. Soc., Trans., vol. 7, Sec. IV, pp. 97–108, pl.
Petrographic description of rocks collected and notes on the general geology of the region.

COLLETT, John. Indiana.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 198–207.
Geological notes for railway stations.

Colorado, charcoal in Custer County, CHARLTON.

Building stones, MERRILL, G. P.

Colorado group, STEVENSON.

Eruptive rocks of Boulder County, PALMER.

Eruptions of Spanish Peaks region, HILLS.

Extinct volcanoes, LAKES.

Formations of eastern Colorado, CANNON.

Huerfano beds, HILLS.

Laramie group, COPE. NEWBERRY. STEVENSON. WARD, L. F.

Movements in Rocky Mountains, EMMONS.

Macfarlane's Railway Guide, EMMONS.

Northwestern Colorado, WHITE, C. A.

Plications of coal measures, VAN DIEST.

Pre-Cambrian of the Black Hills of Dakota, VAN HISE.

Primary quartz in basalts, IDDINGS.

Report—Rocky Mountain division, U. S. Geol. Survey, EMMONS.

Secondary minerals of amphibole and pyroxene groups, CROSS.

Stratigraphic studies in Denver basin, ELDRIDGE.

Structural features near Denver, ELDRIDGE.

Warren's Geography, BREWER.

Colorado Scientific Society, Proceedings, vol. 3, part 2.

Plications in coal measures in southeast Colorado, VAN DIEST.

Digitized by Google

Colorado Scientific Society, Proceedings—Continued.

Dinosaurs, etc., in Laramie of Montana, CANNON.

Formations of eastern Colorado, CANNON.

Note on Huerfano beds, HILLS.

Eruptions of Spanish Peaks region, HILLS.

Eruptive rocks of Boulder County, PALMER.

COMSTOCK, Theodore B. A preliminary report on the geology of the central mineral region of Texas.

Texas, Geol. Survey, First Annual Report, pp. 237–391, pl. 2.

Abstract, Am. Geologist, vol. 6, p. 123, 4 lines.

Archean, Eparchean, Cambrian, Silurian, and Devonian? formations. Eruptives. Structure, Carboniferous to Tertiary uplifts. Economic geology, pp. 329–378. List of minerals, 379–391. Plate of geologic sections.

[CONDON, Thomas.] Oregon.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 316–317.

Geological notes for railway stations.

Connecticut, Archean axes, DANA.

Boring at New Haven, HUBBARD.

Building stone, MERRILL, G. P.

Glacial action in southeastern Connecticut, WELLS.

Fillings in fissures at Meriden, DAVIS.

Glacial scratches near Norfolk, CORNISH.

Limestone at Norfolk, DANA.

Madison Boulder, CROSBY.

Subaerial decay of rocks, DANA.

Macfarlane's Railway Guide, HITCHCOCK.

Taconic Mountains, AM. GEOLOGIST.

Traps of East Haven-Branford region, HOVEY, E. O.

Warren's Geography, BREWER.

COOPER, J. G. The value of fossils as indicators of important mineral products.

California, Ninth Report of Mineralogist, pp. 284–286.

Comprises some general statements regarding the distribution of Quaternary, Tertiary, Cretaceous, Jura-Trias, Carboniferous, and Archean formations in California.

—— California.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 318–323, 324–328.

Geological notes for railway stations.

COOPER, W. F. The Waverly group.

Denison University, Sci. Lab., Bull., vol. 5, pp. 24–32.

Descriptions of the formation in central and northern Ohio.

COPE, E. D. [Remarks on the age and stratigraphic components of the Laramie group.]

Geol. Soc. Am., Bull., vol. 1, p. 532.

Am. Naturalist, vol. 24, p. 569.

Abstract, Am. Geologist, vol. 5, p. 118, 4 lines.

Discussion of paper by J. S. Newberry, "The Laramie Group."

—— The Silver Lake of Oregon and its origin.

Am. Naturalist, vol. 23, pp. 970–982, pls. 40, 41. 1889.

Contains incidental references to the geology.

[——] [Remarks on beds in which Nampa image was found.]

Am. Naturalist, vol. 24, p. 205, 3 lines.

Reference to their age and equivalency.

[——] Macfarlane's American Geological Railway Guide.

Am. Naturalist, vol. 24, p. 952, ½ p.

Includes a brief criticism on the use of the term "Niobrara."

CORNISH, R. H. Glacial scratches in the vicinity of Norfolk, Connecticut.

Am. Jour. Sci., 3d series, vol. 39, p. 321, ⅛ p.

Directions.

COX, E. T. An extensive deposit of phosphate rock in Florida.

Am. Naturalist, vol. 24, pp. 1185–1186, ⅔ p.

Some general statements in regard to its distribution, characteristics, and probable origin.

CRAGIN, F. W. On the Cheyenne sandstone and the Neocomian shales of Kansas.

Washburn Coll., Lab., Bull., vol. 2, pp. 69–80.

Am. Geologist, vol. 6, pp. 238–238.

Abstract, Popular Science Monthly, vol. 37, pp. 566–567, ½ col.

Stratigraphic and paleontologic equivalency.

CRAMER, Frank. On a recent rock flexure.

Am. Jour. Sci., 3d series, vol. 39, pp. 220–225.

An account of slight flexings in limestone in the valley of Fox River, Wisconsin, and discussion of their nature and cause.

CRAWFORD, J. [Letter on the geology of Nicaragua.]

Science, vol. 15, pp. 30–32, 4°.

In connection with the occurrence of footprints described in the containing paper by Earl Flint.

Digitized by Google

CRAWFORD, J.—Continued.

—— The geological survey of Nicaragua.
Am. Geologist, vol. 6, pp. 377-381.
Brief notices of characteristics and distribution of volcanic, Pleistocene, Tertiary, Mesozoic, Permian, Carboniferous, Devonian, and crystalline rocks.

Cretaceous. *Atlantic coastal region.* Deposits of eastern Massachusetts, SHALER.
Analyses of clay and sand from Martha's Vineyard, CLARKE, F. W. RIGGS.
Gay Head, Massachusetts, CLARK. MERRILL, F. J. H. WARD, L. F.
Cretaceous fossils, Martha's Vineyard, SHALER. WHITE, D.
Report—Atlantic coast division, U. S. Geol. Survey, SHALER.
Ancient shore lines, MERRILL, F. J. H.
Long Island Sound and submerged channel of the Hudson, DANA.
Traps of Newark system in New Jersey region, DARTON.
Clay at Monmouth junction, New Jersey, MARTIN. BRITTON.
North American Mesozoic, WHITE, C. A.
Distribution of fossil plants, WARD, L. F.
Macfarlane's Railway Guide. CHANCE. CHESTER. FONTAINE. SMITH and GESNER. HAMMOND, H. MCCUTCHEN. SMOCK. UHLER.
Rivers of northern New Jersey, DAVIS.
Topographic development of New Jersey, DAVIS and WOOD.
Amboy clays, NEWBERRY.
Artesian wells, New Jersey, NASON.
Gabbros of Delaware, CHESTER.
Report—Division of paleobotany, U. S. Geol. Survey, WARD, L. F.
[Age of Potomac formation.] Report—U. S. Geol. Survey, MARSH.
Southern Maryland, CLARK.
Potomac flora, FONTAINE.
Fossil wood of Potomac formation, KNOWLTON.
Southern extension of Appomattox formation, MCGEE.
Southern drift of Georgia, SPENCER.
Cape Fear River region, North Carolina, CLARK.
Warren's Geography, BREWER.

Cretaceous—Continued.
Canada, Cretaceous of Manitoba, TYRRELL.
Duck and Riding Mountains, TYRRELL.
Northwestern Manitoba, TYRRELL.
North American Mesozoic, WHITE, C. A.
Distribution of fossil plants, WARD, L. F.
Expedition down Anderson River, DAWSON, G. M.
Mineral wealth of British Columbia, DAWSON, G. M.
Yukon and Mackenzie Rivers, MCCONNELL.
Chalk, DAWSON, J. W.
Macfarlane's Railway Guide, DAWSON, G. M.
Laramie and its associates, TYRRELL.
Seaboard of British Columbia, BOWMAN.
Notes on British Columbia, DAWSON, G. M.
Caribou district, British Columbia, BOWMAN.
Yukon district, DAWSON, G. M.
Lower Liard River, MCCONNELL.
Warren's Geography, BREWER.
Great Plains and Rocky Mountain region, Cheyenne sandstone of Kansas, CRAGIN.
Chalk from Niobrara of Kansas, WILLISTON.
Kansas salt mine, HAY.
Lignite in Dakota formation, HAY.
Macfarlane's Railway Guide, BAILEY, G. E. ELDRIDGE. EMMONS. BROADHEAD. CHAMBERLIN. GILBERT. HAGUE. MCGEE. PUMPELLY. PUTNAM. ST. JOHN. SCOTT. TODD. UPHAM. WINCHELL, N. H.
Southwestern Kansas, HAY.
Lineage of Lake Agassiz, TODD.
Terraces of the Missouri, TODD.
North American Mesozoic, WHITE, C. A.
Artesian wells in Dakota, UPHAM.
Laramie, Montana, CANNON.
Report of Geologist of Wyoming, RICKETTS.
Yellowstone Park, IDDINGS. HAGUE.
Skull of Ceratopsidæ, MARSH.

Digitized by Google

Cretaceous—Continued.

Great Plains and Rocky Mountain region—Continued.

Northwestern Colorado region, WHITE, C. A.

Coal measures in Colorado and New Mexico, VAN DIEST.

Crazy Mountains, Montana, WOLFF.

Distribution of fossil plants, WARD, L. F.

Custer County, Colorado, CHARLTON.

Eruptive rocks of Boulder County, Colorado, PALMER.

Areas of continental progress in North America, DANA.

Huerfano beds, HILLS.

Colorado group in Colorado and New Mexico, STEVENSON.

Laramie group. COPE. NEWBERRY. STEVENSON. WARD, L. F.

Spanish Peaks region, HILLS.

Rocky Mountain protaxis, DANA.

Movements in Rocky Mountains, EMMONS.

Displacements in Grand Cañon, WALCOTT.

Warren's Geography, BREWER.

Lower Cretaceous of San Carlos Mountains, New Mexico, WHITE, C. A.

Texas region, American Neocomian, MARCOU.

Central coal field Texas, CUMMINS.

Macfarlane's Railway Guide, HILGARD. LOUGHRIDGE. OWEN.

Concho country, Texas, CUMMINS and LEACH.

Trans-Pecos Texas, STREERUWITZ.

Review of Texas geology, DUMBLE.

Areas of continental progress in North America, DANA.

Geographic features of Texas, HILL.

Igneous rocks of central Texas, HILL and DUMBLE.

Fossils of the Trinity beds, HILL.

List of invertebrates of Cretaceous of Texas, and short description of the system, HILL.

Pilot Knob, HILL.

Occurrence of Goniolina in the Comanche series, HILL.

Permian of Texas, CUMMINS.

Central Texas, TARR.

Central mineral region of Texas, COMSTOCK.

Cretaceous—Continued.

Texas region—Continued.

Carboniferous of central Texas, TARR.

Coal fields of Colorado River, TARR.

Report—Division of Mesozoic paleontology, U. S. Geol. Survey, WHITE, C. A.

Cretaceous rocks of Texas, HILL.

Eastern Arkansas, CALL.

Analysis of eruptive from Arkansas, EAKINS.

Northern Mexico, WHITE, C. A.

Report—Division of Mesozoic invertebrates, U. S. Geol. Survey, WHITE, C. A.

Indian Territory and Red River, HILL.

Warren's Geography, BREWER.

Mexico, Geological map, CASTILLO.

Kentucky, Macfarlane's Railway Guide, PROCTOR.

Pacific coast, northern California, DILLER.

Lassen Peak District, DILLER.

Sandstone dikes, DILLER.

Geology of quicksilver deposits, BECKER.

Report—Division of volcanic geology, U. S. Geol. Survey, DUTTON.

Report—California Division, U. S. Geol. Survey, BECKER.

Macfarlane's Railway Guide, CONDON. COOPER. DUTTON. TURNER. WILLIS.

Warren's Geography, BREWER.

South America, Sergipe-Alagoâs region, Brazil, BRANNER.

CROSBY, W. O. [Remarks on evidence in the till as to the climate of the glacial period.]

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 466–467, ¶ p.

Abstract. Am. Geologist, vol. 5, pp. 123–124, 9 lines.

Brief statements in regard to composition and relations of the till, especially in the Boston region, in their bearing on conditions of rock decomposition and climate during the glacial period.

—— Geological history of the Boston basin.

Boston Soc. Nat. Hist., Proc., vol. 25, pp. 10–17.

Abstract of a lecture in which a general description is given of the geology of the region.

Digitized by Google

CROSBY, W. O.—Continued.

—— The Kaolin in Blandford, Massachusetts.

Technology Quart., vol. 3, pp. 228–237.

Descriptions of its geologic relations and associated rocks, and discussion of its preglacial age and of rock decay in general in New England.

—— The Madison bowlder.

Appalachia, vol. 6, pp. 61–70, 105, pl. 5.

Description of the bowlder and discussion of its source. Includes a reference to a similar bowlder in Connecticut.

—— Massachusetts.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 99–107.

Geological notes for railway stations and table of geological formations of the State.

CROSS, Whitman. Notes on some secondary minerals of the amphibole and pyroxene groups.

Am. Jour. Sci., 3d series, vol. 39, pp. 359–370.

Includes brief prefatory statements in regard to the dike in Custer County, Colorado, from which the specimens were obtained.

CROSSMAN, James H. San Bernardino County.

California, Ninth Report of Mineralogist, pp. 214–239.

Incidental references to geology at various points.

CUMMINS, W. F. The southern border of the central coal field.

Texas, Geol. Survey, First Annual Report, pp. 143–182.

Stratigraphy, Cretaceous and Permian formations, dips, economic geology, soils, artesian wells.

—— The Permian of Texas and its overlying beds.

Texas, Geol. Survey, First Annual Report, pp. 183–197.

Distribution, stratigraphy, and economic geology of the Permian, and characteristics of two overlying formations of undetermined age.

—— and **LERCH**, Otto. A geological survey of the Concho country, State of Texas.

Am. Geologist, vol. 5, pp. 321–335, map.

Physiography, Pleistocene, Cretaceous, and Permian formations. Economic geology.

CURTIS, J. S. The banket deposits of the Witwatersrand.

Engineering and Mining Jour., vol. 49, pp. 200–201, 4°.

South Africa.

D.

Dakotas, Artesian wells, UPHAM.

Lineage of Lake Agassiz, TODD.

Pre-Cambrian of the Black Hills, VAN HISE.

Report—Division of vertebrate paleontology, U. S. Geol. Survey, MARSH.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, BAILEY. CHAMBERLIN. DAWSON, G. M. PUMPELLY. TODD. WINCHELL. N. H.

DALL, William Healey. Contributions to the Tertiary fauna of Florida, with especial reference to the Miocene silex beds of Tampa and the Pliocene beds of Caloosahatchie River.

Wagner Inst. Sci., Trans., vol. 3, part 1, pp. 200, pls. 12.

Contains incidental references to the fossiliferous strata.

—— [Remarks on the paleontology of the northwest coast of the United States.]

Am. Naturalist, vol. 24, pp. 1223-1224.

Read to Biological Society of Washington, 1890.

References to Tertiary and Pleistocene of western Oregon and California.

DALL, William Healey—Continued.

—— Report—Division of Cenozoic invertebrates.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 123–127, 1889.

Includes brief references to observations on Miocene marls of southern New Jersey and to explorations by Joseph Willcox in south-central Florida.

DANA, James D. Areas of continental progress in North America and the influence of the conditions of these areas on the work carried forward within them.

Geol. Soc. Am., Bull., vol. 1, pp. 36–48.

A general review of the conditions attending the various stages of geologic development of No. th America.

—— North American geology and palæontology for the use of amateurs, students, and scientists, by S. A. Miller.

Am. Jour. Sci., 3d series, vol. 29, p. 67, ½ p.

Review of use of term Taconic.

—— Sedgwick and Murchison: Cambrian and Silurian.

Am. Jour. Sci., 3d series, vol. 39, pp. 167–180, 235.

Review of early history of Silurian and Cambrian nomenclature.

Digitized by Google

DANA, James D.—Continued.

Archean axes of eastern North America.

Am. Jour. Sci., 3d series, vol. 39, pp. 378–383.
Classification of the axes and discussion of geologic history and the origin of the troughs.

—— Rocky Mountain protaxis and the post-Cretaceous mountain-making along its course.

Am. Jour. Sci., 3d series, vol. 40, pp. 181–196.
Review of history and relations of uplifts in the Rocky Mountain region in the United States and Canada.

—— Long Island Sound in the Quaternary era, with observations on the submarine Hudson River channel.

Am. Jour. Sci., 3d series, vol. 40, pp. 425–437, pl. x.
Review of the glacial and post-glacial history of the sound depression and a discussion of the bearing of the submarine Hudson River channel on the Jura-Trias to Champlain history of the middle Atlantic coastal region.

—— Characteristics of volcanoes with contributions of facts and principles from the Hawaiian Islands, including a historical review of Hawaiian volcanic action for the last sixty-seven years, a discussion of the relations of volcanic islands to deep-sea topography, and a chapter on volcanic island denudation, XVI, 399 pages, 16 plates. New York, 1890.

Abstracts, Am. Jour. Sci., 3d series, vol. 39, pp. 323–324. Am. Geologist, vol. 6, pp. 194–195.

[——] The geological and natural history survey of Minnesota for the year 1888, the 17th annual report, by N. H. Winchell, State geologist.

Am. Jour. Sci., 3d series, vol. 39, pp. 67–68, ½ p.
List of papers, and review of N. H. Winchell on the correlation of Animikie iron ores with those of the Taconic region of New England.

[——] Subaerial decay of rocks and origin of the red color of certain formations. [By I. C. Russell.] Bull. U. S. Geol. Survey, No. 52.

Am. Jour. Sci., 3d series, vol. 39, pp. 317–319.
Description of the memoir and review of conclusions concerning the origin of the red color of the Triassic formation and certain features of subaerial decay in New England.

[——) Archean limestones and other rocks in Norfolk, Connecticut.

Am. Jour. Sci., 3d sees, vol. 39, p 321, ½ p.

DANA, James D.—Continued.

References to observations of R. H. Cornish on mineralogic characteristics and geologic relations of the limestones.

[——] Presidential address before the Geological Society of London.

Am. Jour. Sci., 3d series, vol. 40, pp. 254–255.
On ocean basins. Abstracts and brief mention of the bearing of American geological history on the subject.

[——] Fossils in the Taconic limestone belt at the west foot of Taconic range in Hillsdale, New York.

Am. Jour. Sci., 3d series, vol. 40, pp. 256–257.
Refers to relations of the limestones and paleontological evidence as to their age.

[——] [Notes on the Bernardston series.]

Am. Jour. Sci., 3d series, vol. 40, pp. 263, 265, ½ p.
Historical references and statement in regard to Emerson's investigations of the series.

[——] [Notes on geology of eastern New York.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 137–138.
In regard to the age and distribution of the lower Paleozoics.

DARTON, Nelson Horatio. The relations of the traps of the Newark system in the New Jersey region.

U. S. Geol. Survey, Bull., No. 67, pp. 82, pls. 6.
Descriptions of the structure and relations of the various trap masses, and differentiation of intrusives and extrusives. Illustrated by a colored geologic map.

—— On the occurrence of basalt dikes in the upper Paleozoic series in central Appalachian Virginia, with notes on the petrography, by J. S. Diller.

Am. Jour. Sci., 3d series, vol. 39, pp. 269–271.
Brief account of their location and geologic relations.

[——] [Notes on southeastern New York and northeastern New Jersey.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 110, 128, 130, 132, 133, 134.
Geological notes regarding the Palisade trap and the geology at some stations in Orange County, New York.

DAVIS, William Morris. Structure and origin of glacial sand plains.

Geol. Soc. Am., Bull., vol. 1, pp. 195–202, pl. 3.
Abstract, Am. Naturalist, vol. 24, p. 208, ½ p.
Description of structural characteristics and discussion of their origin and history.

Digitized by Google

DAVIS, William Morris—Continued.

[Remarks on evidence of unconformity between Hudson and Helderberg rocks in the Hudson Valley, New York.]

Geol. Soc. Am., Bull., vol. 1, pp. 354–355, ½ p.

Brief review of the relations in the Catskill and Rondout regions.

—— [Remarks on structure of fillings in fissures in trap at Meriden, Connecticut.]

Geol. Soc. Am., Bull., vol. 1, p. 442, ½ p.

Discussion of the history of the fillings.

—— [Remarks on certain peculiarities of drainage in the Columbia formation overlying the Appomattox.]

Geol. Soc. Am., Bull., vol. 1, p. 548.

In connection with paper by W J McGee, on the southern extension of the Appomattox formation. Points out a hitherto undesignated class of drainage.

—— The rivers of northern New Jersey, with notes on the classification of rivers in general.

National Geographic Magazine, vol. 2, pp. 81–110.

A discussion of the genetic relations of rivers of different kinds, an analysis of the relation and history of the drainage of northern New Jersey and a review of the history of the Green River in the Uinta Mountains.

—— The ice age in North America, and its bearings on the antiquity of man, by G. Frederick Wright; with an appendix on the probable cause of glaciation, by Warren Upham, New York, 1890.

Appalachia, vol. 6, pp. 72–73.

Discusses the evidence concerning a glacial ice dam in the Ohio.

—— The level of no strain.

Am. Geologist, vol. 5, pp. 190–191.

Review of conditions involved and their consequence in the cooling and contraction of the earth's crust.

—— The Iroquois beach.

Am. Geologist, vol. 6, p. 400, ½ p.

Remarks in regard to outlets of Lake Iroquois and the glacial Lake Ontario.

[——] [Utah.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 114, 115, ½ p.

Geological notes for railway stations in the Ogden and Salt Lake regions.

—— and **WOOD**, J. Walter, jr. The geographic development of northern New Jersey.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 365–423.

Abstract, Am. Geologist, vol. 6, pp. 195–196, ½ p.

An analysis of the history recorded in the topography and drainage of the region.

DAWSON, George M. Report on an exploration in the Yukon district, Northwest Territory, and adjacent northern portion of British Columbia. 1887.

Canada, Geol. Survey, Report, vol. 3, new series, part 1, Report B, pp. 183, 4 maps. 1888.

Abstracts, Ibid., Report A, pp. 4–12. Am. Geologist, vol. 5, pp. 240–241, ½ p. Am. Jour. Sci., 3d series, vol. 39, p. 228 ½ p.

Summary account of geologic results of the exploration and incidental itinerary notes and descriptions.

—— The mineral wealth of British Columbia, with an annotated list of localities of minerals of economic value.

Canada, Geol. Survey, Reports, vol. 3, new series, part 2, Report R, pp. 163. 1888.

Description of general geologic features of the region and notes on the various ore deposits, building stones, relations of Tertiary gold-bearing gravels, and stratigraphy of the coal measures.

—— [Account of explorations in southern interior British Columbia.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report A, pp. 60–66. 1888.

Includes brief references to Tertiary coals and trachytes and gold-bearing metamorphic Paleozoics.

—— Notes on the Cretaceous of the British Columbian region. The Nanaimo group.

Am. Jour. Sci., 3d series, vol. 39, pp. 180–183. Abstract, Am. Naturalist, vol. 24, p. 764, ½ p.

Discussion of its extent, stratigraphic range, history, and equivalency.

—— On the glaciation of the northern part of the Cordilleras, with an attempt to correlate the events of the glacial period in the Cordillera and Great Plains.

Am. Geologist, vol. 6, pp. 153–162.

Includes a discussion of the extent of Cordillera glaciers and the glacial history of both regions, and an account of the distribution of the glacial formations.

—— Introductory. On an expedition down the Begh-ula or Anderson River, by R. Macfarlane.

Canadian Record of Science, vol. 4, pp. 28–29.

Includes remarks on the geology.

Digitized by Google

DAWSON, George M.—Continued.

The chalk from the Niobrara Cretaceous of Kansas.

Science, vol. 16, p. 276, ¼ col. 4°.

Refers to certain microscopic organisms in Niobrara beds of Manitoba.

—— The Dominion of Canada.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 51–83.

Geological notes for stations on railway and steamboat routes.

[——] Northern Pacific railroad.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 258–260, 261, 262.

Geological notes for stations at intervals through Dakota, Montana, Idaho, Washington, and Oregon.

DAWSON, J. William. On new species of fossil sponges from the Siluro-Cambrian at Little Metis on the Lower St. Lawrence.

Canada, Roy. Soc., Trans., vol. 7, section iv, pp. 31–55, pl. iii. 4°.

With a brief prefatory description of the geology of the locality and discussion of the age of the beds.

—— On fossil plants collected by Mr. R. A. McConnell on Mackenzie River, and by Mr. T. C. Weston on Bow River.

Canada, Roy. Soc., Trans., vol. 7, section iv, pp. 69–74, pls. x, xi, 4°.

Discussion of the equivalency and age of containing formations.

—— On burrows and tracks of invertebrate animals in Paleozoic rocks, and other markings.

Geol. Soc., Quart. Jour., vol. 47, pp. 595–617.

Includes descriptions and illustrations of various kinds of inorganic markings.

—— The Quebec group of Logan.

Canadian Record of Science, vol. 4, pp. 133–143.

General discussion of its stratigraphic status, nomenclature, and equivalency.

—— Fossil plants from the Similkameen River and other places in the southern interior of British Columbia.

Science, vol. 15, p. 373, ¼ col. 4°.

Abstract of paper read to Royal Society of Canada, 1890.

—— On the Pleistocene flora of Canada. Geology of the deposits.

Geol. Soc. Am., Bull., vol. 1, pp. 311–320.

Abstract, Am. Naturalist, vol. 24, pp. 293–294.

General account of the deposits, brief descriptions of the plant localities, and discussion of geographic and climatic conditions.

DEEKS, William. The Lower Helderberg formation of St. Helen's Island.

Canadian Record of Science, vol. 4, pp. 105–109.

Characteristics, fossils, eruptives, equivalence in New York series.

DE GROOT, Henry. The manufacture of glass in California. History, condition, and future of the business.

California, Ninth Report of Mineralogist, pp. 324–329.

Includes brief description of glass sand deposit in Placer County.

Delaware, Gabbros and associated rocks, CHESTER.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, CHESTER.

Denison University, Scientific Laboratories, Bulletin, vol. 5.

Waverly group, COOPER, W. F.

Devonian.

Alabama, Macfarlane's Railway Guide, SMITH AND GESNER.

Canada, Report on Quebec, ELLS.

Acadian and St. Lawrence watershed, BAILEY.

Review of Ells on geology of Quebec, WALCOTT.

Northwestern Manitoba, TYRRELL.

Duck and Riding Mountains, TYRRELL.

Geology of Ontario, BELL.

New Brunswick, BAILEY, BAILEY and MCINNES.

Expedition down Anderson River, DAWSON, G. M.

Yukon and Mackenzie Rivers, MCCONNELL.

Lower Liard River, MCCONNELL.

Warren's Geography, BREWER.

Central America, Nicaragua, CRAWFORD.

England, Devonshire, WILLIAMS, H. S.

Illinois, Macfarlane's Railway Guide, WORTHEN.

Iowa, Macfarlane's Railway Guide, MCGEE.

Kentucky, oil field of Barren County, FISCHER.

Macfarlane's Railway Guide, PROCTOR.

Warren's Geography, BREWER.

Middlesborough, BOYD.

Maine, Eastern Maine and New Brunswick, BAILEY.

Digitized by Google

Devonian—Continued.
Massachusetts, Bernardston series, EMERSON. DANA.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, HITCHCOCK.
New Jersey, Macfarlane's Railway Guide, SMOCK.
New York, Cuboides zone, WILLIAMS, H. S.
Thickness of rocks in west-central New York, PROSSER, C. S.
Areas of continental progress in North America, DANA.
Paleozoic fishes, NEWBERRY.
Rock salt deposits, western New York, NEWBERRY.
Locality numbers, HALL.
Supposed dikes at Ithaca, KEMP.
Report on oil and gas, CARLL.
Macfarlane's Railway Guide, LINDSEY. WILLIAMS, H. S.
Ohio and Indiana, Waverly group, COOPER.
Analysis of Defiance limestone, WHITFIELD, J. E.
Trenton limestone oil and gas, ORTON.
Geological survey of Ohio report, ORTON.
Report on oil and gas, CARLL.
Paleozoic fishes, NEWBERRY.
Macfarlane's Railway Guide, COLLETT. ORTON.
Pennsylvania, Making of Pennsylvania, CLAYPOLE.
Report on oil and gas, CARLL.
Paleozoic fishes, NEWBERRY.
Macfarlane's Railway Guide, LESLEY. LEWIS.
Warren's Geography, BREWER.
Tennessee, Central basin of Tennessee, KENNEDY.
Macfarlane's Railway Guide, SAFFORD.
Warren's Geography, BREWER.
Virginias and Maryland, Dikes in Appalachian Virginia, DARTON.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, CAMPBELL. FONTAINE. WHITE, I. C.
Western United States, Report—Montana division, U.S. Geol. Survey, PEALE.
Macfarlane's Railway Guide, BROADHEAD. CHAMBERLIN. HAGUE. WINCHELL, A. WINCHELL, N. H.

Devonian—Continued.
Western United States—Continued.
Review of Texas geology, DUMBLE.
Central mineral region of Texas, COMSTOCK.
Displacements in Grand Cañon, WALCOTT.
Cuboides zone, WILLIAMS, H. S.
Nomenclature, Hercynian question, CLARKE.

DILLER, J. S. Geology of the Lassen Peak district.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 395–432, plates XLV–LI, 1889.

Abstract, Am. Geologist, vol. 6, pp. 196–197, ½ p.

Description of hypsography, auriferous slate series, geologic history, Cretaceous to Quaternary, structure of the Sierras, and relations of the displacements of the Sierras to each other and to volcanic phenomena.

—— Report—Division of petrography.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 98–100.

Includes brief references to the crystallization of porphyritic quartz in eruptive rocks and the discovery of chalk in Texas by R. T. Hill.

—— Notes on the Cretaceous rocks of Northern California.

Am. Jour. Sci., 3d series, vol. 40, pp. 476–478.

Description of two sections in the northern part of the Sacramento Valley.

—— Sandstone dikes.

Geol. Soc. Am., Bull., vol. 1, pp. 411–442, plates 6–8.

Abstracts, Am. Geologist, vol. 5, p. 121, ½ p.; Am. Naturalist, vol. 24, p. 211, 6 lines; pp. 768–769, 6 lines; Am. Jour. Sci., 3d series, vol. 40, p. 331, ½ p.

Descriptions of dikes in northern California and discussion of their nature, origin, history, and significance. Includes references to dikes observed in other localities. Discussed by W. M. Davis and B. K. Emerson, p. 442.

—— Petrographic notes. [Basalt dikes in upper Paleozoic series in central Appalachian Virginia.]

Am. Jour. Sci., 3d series, vol. 39, pp. 270–271.

Abstract, Am. Naturalist, vol. 24, pp. 773–774, 5 lines.

Description of the rocks and reference to other dikes in the Great Valley and in Loudoun County, Virginia.

DODGE, W. W. Some lower Silurian graptolites from northern Maine.

Am. Jour. Sci., 3d series, vol. 40, pp. 153–155.

Descriptions of the remains and reference to their stratigraphic equivalency.

Digitized by Google

DRYER, Charles R. The glacial geology of the Irondequoit region.

Am. Geologist, vol. 5, pp. 202–207.

Topographic features and glacial deposits and their history.

DUDLEY, William L. A curious occurrence of Vivianite [near Eddyville, Ky].

Am. Jour. Sci., 3d series, vol. 40, pp. 120–121.

Brief prefatory account of inclosing strata.

DUMBLE, E. T. Results. A review of Texas geology as developed by the work of the Survey.

Texas, Geol. Survey, First Annual Report, pp. xxix–lxxiv, plate 1.

Summary descriptions and taxonomic table of formations from Quaternary to Archean.

—— and **HILL**, R. T. The igneous rocks of central Texas. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 38, pp. 242–243, ½.

Notice of their distribution, general relations, and age.

DUTTON, C. E. Report—Division of volcanic geology.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 156–165, 1889.

Brief description of the exploration of Crater Lake, and in northern California and western Oregon.

—— Atlantic and Pacific Railroad.

Macfarlane's Geol. Railway Guide, 2d edition, p. 323.

Geological notes for stations in New Mexico and Arizona.

DWIGHT, W. B. Fossils of the western Taconic limestone in the eastern part of Dutchess County, New York.

Am. Jour. Sci., 3d series, vol. 39, p. 71, ½ p.

Reviews their bearing on geology of Dutchess County limestones.

—— Discovery of a locality of Trenton limestone rich in ostracoid entomostraca and other fossils at Pleasant Valley, New York.

Vassar Inst., Trans., vol. 5, pp. 75–77.

Includes a brief prefatory description of the containing strata.

—— The Cambrian system of strata.

Vassar Inst., Trans., vol. 5, pp. 98–102.

A brief general review of Cambrian classification.

—— Discovery of fossiliferous strata of the middle Cambrian at Stissing, New York.

Vassar Inst., Trans., vol. 5, pp. 102–109.

Has a brief prefatory note regarding the inclosing strata and their relations.

—— Glacial phenomena.

Vassar Inst, Trans., vol. 5, pp. 116–118.

Brief reviews of opinions in regard to glaciation and the accumulation of ice masses.

[——] [Notes on southeastern New York.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 111, 130–131, 233, 134, 135–137.

Geological notes for railway stations and adjoining regions.

E.

EAKINS, L. G. Rocks from New Mexico. [Analyses.]

U. S. Geol. Survey, Bull. No. 60, p. 155, ½ p.

Obsidian and basalts from Rio Grande Cañon.

—— Sandstones, Berea, Ohio. [Analysis.]

U. S. Geol. Survey, Bull. No. 60, p. 158, ½ p.

—— Coquina, coral, coral rocks, etc. [Analyses.]

U. S. Geol. Survey, Bull. No. 60, pp. 163–164.

Coral rocks and soil from Hawaiian Islands; Hammock clay, ocherous deposit, and coquinas from Florida; phosphatic deposit, Sombrero; coralline bottom, Barbadoes, and recent coral, Bermudas.

—— Metamorphic rock from Marion, Kentucky. [Analysis.]

U. S. Geol. Survey, Bull. No. 64 p. 46, ½ p.

—— Porphyry from Pigeon Point, Michigan. [Analyses.]

U. S. Geol. Survey, Bull. No. 64, p. 46, ½ p.

EAKINS, L. G. Penokee-Gogebic rocks from Wisconsin. [Analyses.]

U. S. Geol. Survey, Bull. No. 64, p. 47, ½ p.

—— Eruptive rocks from four miles southeast of Hot Springs, Arkansas. [Analysis.]

U. S. Geol. Survey, Bull. No. 64, p. 48, ½ p.

—— Recent lavas from two miles south of Mount Trumbull, Arizona. [Analysis.]

U. S. Geol. Survey, Bull. No. 64, p. 48, ½ p.

—— Eruptive rocks from Castle Mountain, Montana. [Analysis.]

U. S. Geol. Survey, Bull. No. 64, p. 49, ½ p.

—— [Eruptive] rocks from northern California. [Analyses.]

U. S. Geol. Survey, Bull. No. 64, p. 50, ½ p.

—— [Analyses of adobe soils.]

U. S. Geol. Survey, Bull. No. 64, p. 51, ½ p.

New Mexico, Nevada, and Utah.

—— and **CHATARD**, T. M. Rocks from Montana. [Analyses.]

U. S. Geol. Survey, Bull. No. 60, pp. 152–154.

Digitized by Google

ELDRIDGE, George Homans. On certain peculiar structural features in the foot-hill region of the Rocky Mountains, near Denver, Colorado.

Washington Phil. Soc., Bull., vol. 11, pp. 247–274, map.

Abstract, Am. Naturalist, vol. 24, p. 212, ½ p.

Description of a novel type of structure and of the Cenozoic, Mesozoic, and Archean formations involved and an analysis of the structural development of the region.

—— [Notice of results of stratigraphic studies in the Denver basin.]

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 144–145, ½ p.

Given by S. F. Emmons in report—Rocky Mountain division of geology.

Elisha Mitchell Scientific Society Journal, 1889, part 2.

Conglomerates of Mesozoic in North Carolina, HOLMES, J. A.

ELLS, R. W. Second report on the geology of a portion of the province of Quebec.

Canada, Geol. Survey, Reports, vol. 3, new series, part 2, report R, pp. 1–114, 1888.

Abstract, Ibid., Part 1, Report A, pp. 25–31, 1888; Am. Geologist, vol. 5, pp. 243–246.

Review by C. D. Walcott, Am. Jour. Sci., 3d series, vol. 39, pp. 101–115.

Description of Devonian, Silurian, Cambrian, pre-Cambrian, crystalline and igneous rocks, superficial deposits and structure in eastern Quebec, mainly south of the St. Lawrence. Discussion of various questions of structure and equivalency. Economic minerals, pp. 101–114.

—— [Account of investigations in the St. Lawrence Valley.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 86–91, 1888.

Includes notes on asbestos mining and brief remarks on equivalency of members of the Quebec group.

—— The stratigraphy of the Quebec Group.

Geol. Soc. Am., Bull., vol. 1, pp. 453–468, pl. 10.

Abstract, Am. Geologist, vol. 5, p. 120, 4 lines.

Historical review of opinions, account of recent observations and discussion of their bearing on the structural and stratigraphic succession. Illustrated by geologic map and cross-section of Quebec region.

—— The geology of Quebec City.

Science, vol. 16, p. 359, ½ col.

Brief review of opinions, and expression of an opinion in regard to the horizon of the Citadel rocks.

ELLS, R. W.—Continued.

Geological progress in Canada.

Ottawa Naturalist, vol. 3, pp. 119–145.

A general sketch of the history of geologic explorations in Canada.

EMERSON, Ben. K. A description of the "Bernardston series" of metamorphic upper Devonian rocks.

Am. Jour. Sci., 3d series, vol. 40, pp. 263–275, 363–374.

Detailed descriptions, maps and sections of structure, stratigraphy and relations. With prefatory note by J. D. Dana.

—— [Remarks on vein fillings in till of the Connecticut Valley].

Geol. Soc. Am., Bull., vol. 1, p. 442, ½ p.

Discussion of their origin.

—— [Remarks on metamorphic conglomerates and other metamorphic phenomena in north-central Massachusetts.]

Geol. Soc. Am., Bull., vol. 1, p. 553, ½ p.

Points out certain conditions of metamorphism and their consequences.

—— Porphyritic and gneissoid granites in Massachusetts [abstract].

Geol. Soc. Am., Bull., vol. 1, pp. 559–561.

Characteristics, structural relations, history, and age.

EMMONS, S. F. Report—Rocky Mountain division of geology.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 144–146, 1889.

Includes brief general statement of results attained by G. H. Eldridge on the Tertiary formations of the Denver region.

—— Orographic movements in the Rocky Mountains.

Geol. Soc. Am., Bull., vol. 1, pp. 245–286.

Abstract, Am. Naturalist, vol. 24, pp. 211–212, ½ p.

Comprises a general discussion of the geologic history of the region.

—— [On the age of the beds in the Boisé River region, Idaho.]

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 429–434.

Discussion of the geological horizon of the beds from which the Nampa image was obtained.

—— Colorado.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 289, 297–308.

Prefatory sketch of the geology of the State and geological notes for railway stations.

ENGINEERING AND MINING JOURNAL. The copper mining district of Michigan and its industries.

Engineering and Mining Jour., vol. 50, pp. 358–361, 4°.

Digitized by Google

ENGINEERING AND MINING JOURNAL—Continued.
With some general prefatory remarks on the geology of the region.
gineering and Mining Journal, vol. 49.
Mulatos gold mines, Mexico, JANIN.
Middlesborough, BOYD.
Phosphate beds of Florida, LEDOUX.
Mines of Calico district, California, STORMS.
Oil fields of Barren County, Kentucky, FISCHER.
Banket deposits of Witwatersrand, CURTIS.
DeKaap Transvaal gold fields, FURLONGE.
Gas explorations in Ontario, ASHBURNER.
Charcoal in Custer County, Colorado, CHARLTON.
— Vol. 50.
Arizona's new bonanza, STORMS.
Coal fields of Texas, WEITZEL.
Florida phosphate beds, WYATT.
Ores of Mina Geraes, Brazil, MEZGER.
Engineering and Mining Journal, vol. 50—Continued.
Copper mining district of Michigan. ENG. AND MINING JOURNAL.
Iron ores of the United States, HUNT.
Europe. Cuboides zone, WILLIAMS, H. S.
Devonian in Devonshire, WILLIAMS, H. S.
Fayalite in obsidian of Lipari, IDDINGS and PENFIELD.
Glacial climate, SHALER.
Glacial lunoid furrows, PACKARD.
Great quartzite more recent than the Olenus schist, HOLST.
Lower and middle Taconic, MARCOU.
Natural soda, CHATARD.
Observations in Norway, WILLIAMS, G. H.
Quaternary changes in level, UPHAM.
Recent glacial work, CLAYPOLE.
EVANS, H. A. The relations of the flora to the geological formations in Lincoln County, Kentucky.
Botanical Gazette, 1889.
Not seen.

F.

FAIRBANKS, Harold W. Notes on the character of the eruptive rocks of the Lake Huron region.
Am. Geologist, vol. 6, pp. 162–172.
Abstract, Am. Naturalist, vol. 24, p. 1072, 3 lines.
Mainly on petrography. Brief references to occurrence, history, age, and relations to other rocks.
FAIRBAULT, E. R. [Account of examination of gold-bearing rocks of the Atlantic coast in Halifax county.]
Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 99–100.
Includes a brief statement in regard to the folds of the gold-bearing rocks.
FARRIER, Walter F., MASON, Frank A., and. A notice of Zircon rocks in Archean highlands of New Jersey. [Abtract.]
Am. Assoc. Adv. Science, Proc., vol. 38, pp. 244–245.
Includes remarks on mineralogic constituents of the rocks, and evidence of their intrusive nature.
FEWKES, J. Walter. The origin of the present outline of the Bermudas.
Am. Geol., vol. 5, pp. 88–100.
Discussion of evidences bearing on theories of subsidence and erosion.
—— On excavations made in rocks by sea-urchins.
Am. Naturalist, vol. 24, pp. 1–21, plates 1, 2.
With discussion of the geologic significance of the facts.
FISCHER, Moritz. The oil field of Barren County, Kentucky.
Engineering and Mining Jour., vol. 49, pp. 197–198, 4°.
Geologic map. Sections. Geologic distribution of the oil.
FLETCHER, H. [Account of examinations of Picton and Colchester counties, Nova Scotia.]
Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 97–99, 1888.
Includes brief references to the distribution and relations of the various formations and especially to their economic resources.
FLINT, Earl. About the Nicaragua footprints.
Science, vol. 15, pp. 30–32.

Digitized by Google

FLINT, Earl—Continued.

Discussion of the age and history of the formation. Includes a letter from J. Crawford on the geology of the region.

FLORIDA. Analyses of coquina, clay, and coral rocks, CLARKE, EAKINS.

Barrier beaches, MERRILL, F. J. H.

Macfarlane's Railway Guide, JOHNSON.

Note on coral reefs, AGASSIZ.

Observations on Southern Florida, WILCOX.

Origin of present outlines of the Bermudas, FEWKES.

Phosphate beds, LEDOUX, GOLDSMITH, COX, WYATT.

Pleistocene submergence, SHALER.

Report—Atlantic coast division, U. S. Geol. Survey, SHALER.

Report—Division of Cenozoic invertebrates, U. S. Geol. Survey, DALL.

Tertiary fauna of Florida, DALL.

Topography of Florida, SHALER.

Saliferous deposits as evidence of climatal condition, SHALER.

Warren's Geography, BREWER.

FONTAINE, William Morris. The Potomac or younger Mesozoic flora.

U. S. Geol. Survey, Monographs, vol. 15, vol. 1, 14, 377 pages, vol. 2, 180 plates, 4°, Washington, 1889.

Abstract, Am. Jour. Sci., 3d series, vol. 39, p. 520, ½ p., vol. 40, pp. 168–169, ½ p.

Has prefatory chapter on the location and geology of the Potomac beds and the plant localities, pp. 1–62.

—— [Baltimore and Ohio Railroad.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 333–334.

Geological notes for stations in western Maryland.

[——] [Virginia.]

Macfarlane's Geol. Railway Guide, 2d edition, p. 359, ½ p.

Geological notes for railroads in eastern Virginia.

FORD, S. W.] [Notes on eastern New York.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 111, 131.

Geological notes along New York Central Railway from Rhinebeck to Troy.

Forum, 1890, Encroachments of the sea, MCGEE.

Recent views about glaciers, WINCHELL, A.

FOSHAY, P. Max. Preglacial drainage and recent geological history of western Pennsylvania.

Am. Jour. Sci., 3d series, vol. 40, pp. 397–403.

Conditions and course of preglacial drainage and evidences of post-glacial uplifts.

—— and **HICE**, R. R. Newly discovered glacial phenomena in the Beaver Valley [Pennsylvania].

Am. Naturalist, vol. 24, pp. 816–818.

Notice of gravel deposits, grooves and striæ, and potholes, several miles south of the terminal moraines of previous observers.

FRAZER, Persifor. The session of the International Geological Congress in Philadelphia.

Am. Geologist, vol. 5, pp. 208–212.

Report of proceedings.

[——] [Notes on northern general division Mexican National Railway.]

Macfarlane's Geol. Railway Guide, 2d edition, p. 420, ½ p.

FRIEDERICH, J. J. On some new species of Protozoötites, Quaternary and Tertiary, from California, and on the importance of protozoa as rock-building agents.

New York Acad. Sci., Trans., vol. 9, pp. 32–36.

Includes brief references to the localities and conditions of occurrence.

FURLONGE, W. H. Notes on the geology of the De Kaap Transvaal goldfields.

Engineering and Mining Jour., vol. 49, pp. 287–291, 4°.

South Africa.

G.

GANONG, W. F. Southern invertebrates on the shores of Acadia.

Science, vol. 15, pp. 373–375, ½ col., 4°.

Abstract of paper read to Royal Society of Canada, 1890.

GENTH, F. A. Contributions to Mineralogy. On a new occurrence of Corundum, in Patrick County, Virginia.

Am. Jour. Sci., 3d series, vol. 39, pp. 47–49.

Includes a reference to nature of associated rocks.

Geologic Philosophy.

Petrology.

Origin of soda granites, etc., Pigeon Point, BAYLEY.

Origin of gneiss, BELL.

[Texture of massive rocks.] Report California division U. S. Geol. Survey, BECKER.

Bernardston series, EMERSON.

Primary quartz in basalts, IDDINGS.

Digitized by Google

ɔologic Philosophy—Continued.
Petrology—Continued.
Metamorphic phenomena in Massachusetts, EMERSON.
Pre-Cambrian of the Black Hills, VAN HISE.
Greenstone schists, Menominee and Marquette regions, WILLIAMS, G. H. IRVING.
Granitoid areas in lower Laurentian, HITCHCOCK. WILLIAMS, G. H.
Studies of hornblende schist, HITCHCOCK.
Non-feldspathic intrusives of Maryland, WILLIAMS, G. H.
Granites in Massachusetts, EMERSON.
Dikes of Kennebunkport, Maine, KEMP.
Report on Rainy Lake region, LAWSON.
Report—Division of Petrography, U. S. Geol. Survey, DILLER.
Archean of central Canada, LAWSON.
Serpentines of southeastern Pennsylvania, RAND.
Igneous rocks of Yellowstone Park, IDDINGS.
Petrography for 1887 and 1888, MERRILL, G. P.
Glaciology.
Glacial phenomena in Canada, BELL.
Drift of northern Iowa, WEBSTER.
Glacial phenomena, DWIGHT.
Bowlder belts *vs.* bowlder trains, CHAMBERLIN.
Glacial boundary, Pennsylvania to Illinois, WRIGHT. CHAMBERLIN.
Origin of extra-morainic till, TODD.
Island of Mount Desert, Maine, SHALER.
Cape Ann, Massachusetts, SHALER.
Glacial sediments of Maine, STONE.
Topography of Florida, SHALER.
Origin of glacial sand plains, DAVIS.
Glacial lunoid furrows, PACKARD.
Surface geology of Alaska, RUSSELL.
Quaternary history of Mono Valley, California, RUSSELL.
Recent views about glaciers, WINCHELL, A.
Physiographic geology.
Topographic types, Iowa, MCGEE.
Drainage systems of New Mexico, TARR.
Geologic Philosophy—Continued.
Physiographic geology—Continued.
Drainage in central Texas, TARR.
Topographic features of central Texas, TARR.
Northwestern Colorado and vicinity, WHITE, C. A.
History of the Niagara River, GILBERT.
Certain peculiarities of drainage, DAVIS. MCGEE.
Encroachments of the sea, MCGEE.
Central basin of Tennessee, KENNEDY.
Topography of Florida, SHALER.
Development of northern New Jersey, DAVIS and WOOD.
Rivers of northern New Jersey, DAVIS.
Mount Desert Island, SHALER.
Erosive agents in arid regions, TARR.
Lake Bonneville, GILBERT.
Barrier beaches, MERRILL, F. J. H.
Earth crust deformation.
Proof of earth's rigidity, BECKER.
Strength of the earth's crust, GILBERT. WINCHELL, A.
Level of no strain in earth's crust, CLAYPOLE. DAVIS.
Shear in earth crust movements, STEVENSON.
Origin of diagonal trends in the earth's crust, MARTIN.
History of the Niagara River, GILBERT.
Areas of continental progress in North America, DANA.
Ocean basins, DANA.
Rocky Mountain protaxis, DANA.
Origin of normal faults, READE.
Lake Bonneville, GILBERT.
Displacements in Grand Cañon, WALCOTT.
Recent rock flexure, CRAMER.
Topography of Florida, SHALER.
Chemical and chemico-organic deposits.
Origin of Keewatin ores, WINCHELL, N. H. and H. V.
Quicksilver deposits, BECKER.
Natural gas and oil, ORTON.
Formation of traventine and sinter by vegetation of hot springs, WEED.
Protozoa as rock-building agents, FRIEDRICH.

Digitized by Google

Geologic Philosophy—Continued.
Chemical and chemico-organic deposits—Continued.
Corals and coral islands, DANA.
Phosphate rock in Florida, COX. LEDOUX. WYATT.
Subaerial decay of rocks and origin of red color in certain formations, DANA.
Geological climate.
Climate of glacial period, CROSBY. SHALER.
Pleistocene submergence, UPHAM. SHALER.
Saliferous deposits as evidence of climatal conditions, SHALER.
Volcanism.
Volcanoes, DANA.
Geysers, WEED,
Newark traps of New Jersey region, DARTON.
Lake Bonneville, GILBERT.
Miscellaneous.
Southern extension of Appomattox formation, MCGEE.
Sand transportation by rivers, GRAHAM.
Markings in Paleozoic rocks, DAWSON, J. W.
Lake Bonneville, GILBERT.
Excavations made in rocks by sea-urchins, FEWKES.
Origin of rock pressure of natural gas, ORTON.
Geological survey of Ohio, report, ORTON.
Sandstone dikes, DILLER. DAVIS. EMERSON.
Geology of Cape Ann, SHALER.
Geology for 1887 and 1888, MCGEE.

Geological Magazine, decade III, vol. 7.
Skull of Ceratopsidæ, MARSH.
Continental elevation preceding Pleistocene in America, SPENCER.
Quaternary changes of level, UPHAM.
Data of continental elevation of America, JUKES-BROWNE.

Geological Society of America, Bulletin, vol. 1.
Strength of the earth's crust, GILBERT. WINCHELL, A.
[Lignite in Dakota formation in Kansas], HAY.
[Shear in earth crust movements], STEVENSON.

Geological Society of America, Bulletin, vol. 1—Continued.
Bowlder belts distinguished from bowlder trains, CHAMBERLIN.
[Bowlders in morainal fringe], WRIGHT.
[Distribution of bowlders in Michigan], WINCHELL, A.
[Distribution of bowlders in New England], HITCHCOCK.
Trap dikes near Kennebunkport, Maine, KEMP.
Sylvania sand, Ohio, NEFF.
Areas of continental progress in North America, DANA.
Displacement in Grand Cañon of Colorado, WALCOTT.
Continental elevation preceding Pleistocene period, SPENCER.
Ancient shores, etc., in region of the Great Lakes, SPENCER.
Origin of rock pressure of natural gas, ORTON. MCGEE. WHITE, I. C.
Surface geology of Alaska, RUSSELL.
[Extent and cause of Pleistocene glaciers], CHAMBERLIN.
Pre-Paleozoic surface in Canada, LAWSON.
[Rounded surfaces not due to glacial erosion], SPENCER.
Glacial sand plains, DAVIS.
Pre-Cambrian of the Black Hills, VAN HISE.
Orographic movements in the Rocky Mountains. EMMONS.
Glacial phenomena in Canada, BELL.
Pleistocene flora of Canada, DAWSON, J. W.
Value of term "Hudson River group," WALCOTT.
[Unconformity between Hudson and Helderberg formations], DAVIS.
Results of Archean studies, WINCHELL, A.
[Remarks on crystallines of the Northwest], VAN HISE.
Post-Tertiary deposits of Manitoba, TYRRELL.
[Lake Winnipeg-Mississippi drainage], MILLS.
[Outlet of Lake Agassiz and limits of glaciation], CHAMBERLIN.
[Pleistocene submergence of Atlantic coast], SHALER. MCGEE.

Digitized by Google

Geological Society of America, Bulletin, vol. 1—Continued.

[Evidences of general Pleistocene submergence], SPENCER.

Sandstone dikes, DILLER.

[Vein filling in till], EMERSON.

[Fillings in fissures in trap], DAVIS.

Tertiary and Cretaceous of eastern Massachusetts, SHALER.

Stratigraphy of the Quebec group, ELLS.

Cuboides zone and its fauna, WILLIAMS, H. S.

Evidence on interval between glacial epochs, CHAMBERLIN.

[Formations termed Orange sand], MCGEE.

[Orange sands of western Kentucky], PROCTER.

[Interglacial deposits of the Delaware], MERRILL, F. J. H.

[Glacial deposits of upper Ohio River], WHITE, I. C.

[Pleistocene deposits at Belvidere], MCGEE.

Calciferous in Champlain Valley, BRAINERD and SEELY.

[Calciferous formation from Canada to Tennessee,], WALCOTT.

[Eolian limestone of Vermont], HITCHCOCK.

Fort Cassin rocks and their fauna, WHITFIELD, R. P.

Laramie group, NEWBERRY. TYRRELL. WARD. STEVENSON. COPE.

[Colorado group in Colorado and New Mexico], STEVENSON.

Eruptive origin of Syracuse serpentine, WILLIAMS, G. H.

[Dikes near Ithaca, New York], KEMP.

Tertiary deposits of Cape Fear River region, CLARK.

Glacial features of Yukon and Mackenzie basins, TYRRELL.

Moraine of recession in Ontario, WRIGHT.

[Certain gravel deposits of Ontario], SPENCER.

Southern extension of Appomattox, MCGEE.

[Peculiarities of drainage in Columbia formation], DAVIS. MCGEE.

Observations in Norway, WILLIAMS, G. H.

Geological Society of America, Bulletin, vol. 1—Continued.

[Metamorphism in Massachusetts], EMERSON.

Cretaceous plants from Martha's Vineyard, WHITE, D. WARD. MERRILL, F. J. H.

[Northern extension of Amboy clays], NEWBERRY.

Oval granitoid areas in the Laurentian, HITCHCOCK. WILLIAMS, G. H.

Granites in Massachusetts, EMERSON.

Intrusive origin of Watchung traps of New Jersey, NASON.

Fiords and Great Lake basins of North America, UPHAM.

Potholes north of Lake Superior, MCKELLAR.

Geological Society, Quarterly Journal, vol. 46.

Origin of basins of the Great Lakes, SPENCER. BONNEY. SEELEY. HINDE.

Spherulites from California, RUTLEY.

GEORGIA, Appomattox formation, MCGEE.

Rounded rock surfaces, SPENCER.

Warren's Geography, BREWER.

Southern drift, SPENCER.

Macfarlane's Railway Guide, CAMPBELL. MCCUTCHEN.

Georgia, Bull. Exp. Sta., 1890, Department of Geology.

Southern drift, SPENCER.

[GESNER, William, **SMITH,** Eugene and.] Alabama.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 378–382.

Geological notes for railway stations.

GILBERT, Grove Karl. Lake Bonneville, U. S. Geol. Survey, Monographs, vol. 1, xx, 438 pages, 51 plates, map. 4°. Washington.

Abstracts, Am. Geologist, vol. 7, pp. 132–134, 1891. Am. Jour. Sci., 3d series, vol. 41, pp. 327–329, 1891.

Systematic description of the shore phenomena, Pleistocene deposits, volcanic features and structure of the Bonneville basin, and discussion of its geologic history. Contains chapters on topographic features of lake shores in general, Lake Bonneville and diastrophism, and the age of the Equus fauna. Appendix A, on altitudes and their determination, by A. L. Webster; B, on the deformation of the geoid by the removal, through evaporation, of the water of Lake Bonneville,

Digitized by Google

GILBERT, Grove Karl—Continued.

by R. S. Woodward; and C, on the elevation of the surface of the Bonneville basin, by expansion due to change of climate, by R. S. Woodward.

—— The history of the Niagara River.

New York, Com. State Reservation at Niagara, Sixth Report, pp. 61–84, plates 1–8.

A sketch of the post-Tertiary history of the Great Lakes region, comprising a description and discussion of the phenomena by which its history is recorded, and of the agencies and attendant conditions.

—— The strength of the earth's crust.

Geol. Soc. Am., Bull., vol. 1, pp. 23–24, 26, 27.

Abstracts, Am. Naturalist, vol. 24, pp. 109, 467–470.

Discussion of limits of rigidity and the nature of geologic conditions producing deformation. Discussed by A. Winchell, Robert Hay, J. J. Stevenson, and J. C. Branner, pp. 25–27.

[——] Utah.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 313–315.

Geological notes for railway stations.

GILPIN, E. The evidence of a Nova Scotia Carboniferous conglomerate.

Science, vol. 15, p. 373, ½ col., 4°.

Abstract of paper read to Royal Society of Canada, 1890.

GIROUX, N. J. Serpentines of Canada.

Ottawa Naturalist, vol. 4, pp. 95–116.

Descriptions of all known localities, quoted mainly from various authorities.

GOLDSMITH, Edward. Pea-like phosphorite from Polk County, Florida.

Philadelphia, Acad. Nat. Sciences, Proc., 1890, p. 10, ½ p.

Description of its constitution.

GOODYEAR, W. A. San Diego County.

California, Ninth Report of Mineralogist, pp. 139–155.

Incidental references to geology.

—— Santa Cruz Island.

California, Ninth Report of Mineralogist, pp. 155–170, map.

A description of its geology.

GORDON, C. H. On the Keokuk beds at Keokuk, Iowa.

Am. Jour. Sci., 3d series, vol. 40, pp. 295–300.

Abstract, Iowa Acad. Sci., Proc., 1887–1889, pp. 98–100.

Extent, fauna, stratigraphy and history, of some of the members.

—— On the brecciated character of the St. Louis limestone.

Am. Naturalist, vol. 24, pp. 305–313, plates 10, 11.

Description of the relations and discussion of the history of the formation.

GRAHAM, James C. On a peculiar method of sand transportation by rivers.

Am. Jour. Sci., 3d series, vol. 40, pp. 476, ½ p.

Abstract, Engineering and Mining Jour., vol. 50, p. 648, ½ col., 4°.

Discussion of the floating of sand.

GRANT, Uly S. Account of a deserted gorge of the Mississippi near Minnehaha Falls.

Am. Geologist, vol. 6, pp. 1–6, plate 1.

Account of its topography and review of its history.

GRATACAP, L. P. [Block of Potsdam sandstone from drift on shore at Tottenville, Staten Island.]

Am. Naturalist, vol. 24, p. 695, 8 lines.

Science, vol. 15, p. 14, 4°.

H.

HAGUE, Arnold. Report—Yellowstone National Park division.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 91–96, 1889.

Includes a brief general reference to geology of the upper Yellowstone.

[——] Wyoming, Utah, Nevada, and Idaho.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 309–312, 315.

List of formations and geological notes for railway stations.

[HALL, C. W.] [Notes for Fergus Falls and Black Hills Railway, Gara and Winnebago City.]

Macfarlane's Geol. Railway Guide, 2d edition, p. 251, ½ p.

[HALL, James.] Record of locality numbers.

New York State Museum, Forty-second Report, pp. 451–496, 1889, (to be continued).

Brief reference to fossiliferous localities in the State of New York and adjoining portions of Pennsylvania.

[HAMMOND, Harry.] South Carolina.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 369–373.

Geological notes for railway stations.

HAMMOND, John Hays. The auriferous gravels of California. Geology of their occurrence and methods of their exploitation.

California, Ninth Report of Mineralogist, pp. 105–138, pls. 1–8.

Digitized by Google

AMMOND, John Hays—Continued.

Abstract, Engineering and Mining Jour., vol. 50, pp. 310–311, 2 cols., 4°.

Incidental reference to geology and cross sections of several districts.

arvard College, Museum of Comparative Zoölogy, Bulletins, vol. 16.

Cretaceous fossils on Martha's Vineyard, SHALER.

Topography of Florida, SHALER.

Coral reefs of southern Florida, AGASSIZ.

Ottrelite and Ilmenite schist in New England, WOLFF.

ARVEY, Arthur. Broad outlines of the geology of the northwest of Lake Superior.

Canadian Inst., Proc., new series, vol. 7, pp. 218–225.

Review of geologic history, mainly of the Great Lakes region.

—] Erosion in the valley of the Don.

Canadian Inst., Proc., vol. 7, pp. 28–29, ½ p., 1889.

Discussion of its rate.

[ASTINGS, John B.] Notes for Union Pacific Railroad.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 312, 313, 314.

Geological notes for stations between American Falls, Idaho, and Ketchum, Oregon.

awaiian Islands. Analyses of coral rocks and soils, EAKINS.

Volcanoes, DANA.

AWORTH, Erasmus. The crystalline rocks of Missouri. (Abstract.)

Iowa Acad. Sci., Proc., 1887–1889, pp. 67–68.

General references to the various rocks and their relations.

AY, Robert. A geological reconnaissance in southeastern Kansas.

U. S. Geol. Survey, Bulletin, No. 57, pp. 15–49, pls. 1, 2.

Abstract, Am. Geologist, vol. 6, pp. 389–390, ½ p.

Description of Carboniferous, Jura-Trias, Cretaceous, Tertiary, and Quaternary formations, and discussion of various questions of stratigraphy, equivalency, geologic history, source of the Tertiary conglomerates, position of the Tertiary shores and the history of the unconformities. Colored geologic map and plate of cross-sections.

— Notes on Kansas salt mines.

Am. Geologist, vol. 5, pp. 65–67, pls. 2.

Stratigraphy at Kingman and reference to occurrence of red beds at Ellsworth and of gypsum deposits in Permo-Carboniferous and red beds.

HAY, Robert—Continued.

—— Artesian wells in Kansas and causes of their flow.

Am. Geologist, vol. 5, pp. 296–301.

Sci. Am. Suppl., vol. 29, pp. 12066–12067 No. 755.

Abstract, Kansas Acad. Sci., Trans., vol. 12, pp. 24–25.

Review of conditions affecting artesian water supplies at various localities in Kansas.

[——] [Remarks on certain peculiarities in the distribution of lignite in the Dakota formation in Kansas.]

Geol. Soc. Am., Bull., vol. 1, p. 26, ¼ p.

Reference to local flexures along depressions.

In discussion of paper by G. K. Gilbert. "The strength of the earth's crust."

HEILPRIN, Angelo. The corals and coral reefs of the western waters of the Gulf of Mexico.

Philadelphia, Acad. Nat. Science, Proc., 1890, pp. 303–316, pls. 6, 7.

Includes a description and chart of the reefs and discussion of their history and its bearing on coral reef theories.

HERRICK, C. L. The Philadelphia meeting of the International Congress of Geologists.

Am. Geologist, vol. 5, pp. 379–388.

Record of proceedings.

HEWITT, W. The evolution of the Grand Cañon of the Colorado. A problem in physiographical geology.

Liverpool Geol. Assoc., Jour., vol. 9, pp. 49–55.

Extracts from C. E. Dutton's "Tertiary history of the Grand Cañon District," U. S. Geol. Survey, Monographs, vol. 2, 1882.

HICE, R. R., **FOSHAY**, P. Max, and. Newly discovered glacial phenomena in the Beaver Valley, [Pennsylvania].

Am. Naturalist, vol. 24, pp. 816–818.

Notice of gravel deposits, grooves, striæ, and pot-holes, several miles south of the terminal moraines of previous observers.

[HILGARD, E. W.] Mississippi.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 386, 389.

Brief sketch of the geology of the State and notes for railway stations.

[——] Louisiana.

Macfarlane's Geol. Railway Guide, pp. 390–391.

Geological notes for railway stations.

Digitized by Google

HILL, Robert T. A preliminary annotated check list of the Cretaceous fossils of Texas, accompanied by a short description of the lithology and stratigraphy of the system. Texas Geological Survey, Bulletin No. 4, pp. xxxi. 57. Austin, 1889.

Abstract, Am. Geologist, vol. 6, p. 124, ½ p. Reviewed by J. Marcou, Am. Geologist, vol. 5, pp. 315–317.

Pages vii–xxxi, prefatory general description and stratigraphic table of the Texas section of the Cretaceous.

—— A brief description of the Cretaceous rocks of Texas and their economic value, based principally upon a preliminary section along the Colorado River from near Smithwick Mills, Burnet County, to Webberville, Travis County.

Texas Geol. Survey, First Annual Report, pp. 103–144.

General stratigraphic review of the component formations and description of certain disturbed areas, and of economic features.

—— The Eagle Flats formation and the basin of the Trans-Pecos or mountainous region of Texas. (Abstract.)

Am. Assoc. Adv. Science, Proc., vol. 38, p. 242, 8 lines.

Brief notice of Quaternary lake beds.

—— The geology of the valley of the upper Canadian from Tascosa, Texas, to Tucumcarri Mountain, New Mexico, with notes on the age of the same. (Abstract.)

Am. Assoc. Adv. Science, Proc., vol. 38, p. 243, 5 lines.

Notice of its general topographic relations, and of a detrital filling for which a name is proposed.

—— The geology of the Staked Plains of Texas, with a description of the Staked Plains formation. (Abstract.)

Am. Assoc. Adv. Science, Proc., vol. 38, p. 243, 4 lines.

Notice of history of the plains and application of a name to their Pleistocene deposits.

—— A classification of the topographic features of Texas, with remarks upon the areal distribution of the geologic formations. (Abstract.)

Am. Assoc. Adv. Science, Proc., vol. 38, pp. 243–244, 9 lines.

The abstract consists of a brief general classification of the principal topographic features of the State.

—— Classification and origin of the chief geographic features of the Texas region.

HILL, Robert T.—Continued.

Am. Geologist, vol. 5, pp. 9–29, 68–80, map. (To be continued.)

Description of the various topographic areas and geologic formations and sketch of the history of the topographic development of the region.

—— The fossils of the Trinity beds.

Am. Geologist, vol. 5, p. 62, ½ p.

Remarks in regard to identity of certain forms and reference to general stratigraphic nature of the formation.

—— Exploration of the Indian Territory and the medial third of Red River.

Am. Geologist, vol. 6, pp. 252–253.

Brief statement in regard to relations and structure of folded Paleozoics and a granite belt and discussion of age of the disturbances.

—— The Texas Cretaceous.

Am. Geologist, vol. 6, pp. 253–254, ½ p.

In regard to correlation with European Cretaceous.

—— Pilot Knob. A marine Cretaceous volcano. [Texas.]

Am. Geologist, vol. 6, pp. 286–292.

Abstract, Am. Naturalist, vol. 25, pp. 275, 276, ½ p. 1891.

Geologic relations, ash beds, contact phenomena and Cretaceous, Tertiary and Pleistocene history of the region.

—— Occurrence of Goniolina in the Comanche series of the Texas Cretaceous.

Am. Jour. Sci., 3d series, vol. 40, pp. 64–65.

Includes brief description of containing beds.

—— and **DUMBLE**, E. T. The igneous rocks of central Texas. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 38, pp. 242–243, ½ p.

Notice of their distribution, general relations, and age.

HILLEBRAND, W. F. Rocks from Pigeon Point, Minnesota. Analyses.

U. S. Geol. Survey, Bull. No. 55, pp. 81–82. 1889.

—— [Volcanic] rocks from California. Analyses.

U. S. Geol. Survey, Bull. No. 55, pp. 84–85. 1889.

—— Rocks collected by R. D. Irving. [Gabbro, limestone, and iron carbonate. Analyses.]

U. S. Geol. Survey, Bull. No. 60, pp. 149, 150, ½ p.

Penokee-Gogebic region, Michigan and Wisconsin.

Digitized by Google

LLEBRAND, W. F.—Continued.

ovaculite from Marquette, Michigan. [Analysis.]

U. S. Geol. Survey, Bull. No. 60, p. 151, ½ p.

- Lavas from near Lassen Peak, California. [Analyses.]

U. S. Geol. Survey, Bull. No. 60, pp. 155–157.

- Dolomite from Tuckahoe, Westchester County, New York. [Analysis.]

U. S. Geol. Survey, Bull. No. 60, p. 159, ½ p.

- Marble from Louisiana. [Analysis.]

U. S. Geol. Survey, Bull. No. 60, p. 160, ½ p.

LLS, R. C. Additional note on the Huerfano beds.

Colorado Sci. Soc., Proc., vol. 3, pp. 217–223.

Distribution, relations to marine Cretaceous and to the Laramie, mammalian remains, overlying Pliocene beds, and absence of Eocene fresh-water deposits east of the Rocky Mountain divide.

- Additional notes on the eruptions of he Spanish Peaks region.

Colorado Sci. Soc., Proc., vol. 3, pp, 224–227.

Extent, structural relations and correlation of some of the masses and notice of newly discovered sheets and dikes.

INDE, G. J.] [Remarks on the origin f the basins of the Great Lakes of merica.]

Geol. Soc., Quart. Jour., vol. 46, pp. 531–532, ½ p.

Discussion of paper with that title by J. W. Spencer.

TCHCOCK, C. H. Significance of val granitoid areas in the lower Laurentian. [Abstract.]

Geol. Soc. Am., Bull., vol. 1, pp. 557–558.

Abstract, Am. Geologist, vol. 5, p. 121, 7 lines.

Discussion of the causes and conditions which have given rise to certain concentric arrangements of minerals and structure, instancing an area at Hanover, N. H. Discussed by G. H. Williams, p. 558, ½ p.

[Remarks on the equivalency of the olian limestones of Vermont.]

Geol. Soc. Am., Bull., vol. 1, p. 513, ½ p.

In discussion of paper by E. Brainerd and H. M. Seely on "The Calciferous formation in he Champlain Valley."

[Remarks on distribution of bowlders, especially in New England.]

Geol. Soc. Am., Bull., vol. 1, p. 30, ½ p.

In discussion of paper by T. C. Chamberlin n "Bowlder belts distinguished from bowlder rains."

The use of the terms Laurentian and owark in geological treatises.

HITCHCOCK, C. H.—Continued.

Am. Geologist, vol. 5, pp. 197–202.

Discussion of the status of various terms which have been applied to Archean, Jura-Trias, and late Pleistocene formations.

—— Field studies of hornblende schist. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, p. 251, ½ p.

Evidence of its original eruptive nature, and age of eruption.

—— Maine, New Hampshire, Vermont, and Connecticut.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 86–98.

Table of geological formations of the New England States and geological notes for railway stations.

—— Wright's "Ice age in North America and its bearings on the antiquity of man."

Bibliotheca Sacra, Jan., 1890, pp. 99–121.

A description of the work and a discussion of the events of Pleistocene history, mainly in connection with the age and relations of the Columbia formation.

[——] [Notes on Harlem division New York Central Railroad.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 132, 135.

HOLLAND, W. J. Ascent of the volcanoes Nantai-san, Asama-yama, and Nasu-take, Japan.

Appalachia, vol. 6, pp. 109–137, plates 6–8.

Includes notes on their geologic structure and history.

HOLMES, J. A. The conglomerate and pebble beds of the Triassic and Potomac formations in North Carolina. [Abstract.]

Elisha Mitchell Sci. Soc., Jour., 1889, p. 148, ½ p.

Brief reference to conditions of deposition and bearing on geologic history of the region.

HOLST, N. O. A great quartzyte more recent than the Olenus-schist.

Am. Geologist, vol. 6, pp. 357–360.

From Geologiska Föreningens i Stockholm, Förhandl., bd. 11, p. 33, 1889.

In Sweden.

HOVEY, E. O. Observations on some of the trap ridges of the East-Haven-Branford, Connecticut, region. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 232–233, ½ p.

Abstract, Am. Naturalist, vol. 24, p. 110, 4 lines.

Structural relations, contact features, age and history.

Digitized by Google

HOVEY, Horace C. The pits and domes of Mammoth Cave. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 253–255.

Description of certain recently explored chambers of the cave.

HUBBARD, O. P. [Notice of pot-holes opposite Catskill, New York, and deep boring in Newark sandstones at New Haven, Connecticut.

New York Acad. Sci., Trans., vol. 9, p. 3, ½ p.

Gives elevation and dimensions of pot-holes and brief account of a 2,400-foot boring.

HUNT, Joseph H. A group of copper pseudomorphs after chalcocite, and silica and phrenite pseudomorphs after pectolite, from Paterson, N. J. [Abstract.]

New York Acad. Sci., Trans., vol. 9, pp. 140–144.

HUNT, Joseph H.—Continued.

With prefatory description of the containing altered eruptives.

HUNT, T. Sterry. The iron ores of the United States.

Engineering and Mining Jour., vol. 50, pp. 601–602, 622–624, 4°.

Comprises a discussion of their geologic distribution.

—— The geological history of the Quebec Group.

Am. Geologist, vol. 5, pp. 212–225.

Review of the "Quebec Group" question.

[——] [Notes on geology of eastern New York.]

Macfarlane's Geol. Railway Guide, 2d edition, p. 137.

On the age, equivalency, and relations of the Silurian to Archean rocks.

I.

IDAHO. Age of beds in Boisé River region, EMMONS. COPE.

Macfarlane's Geol. Railway Guide, DAWSON, G. M. HAGUE. HASTINGS. PUMPELLY.

Movements in Rocky Mountains, EMMONS. SCOTT.

Record of well at Nampa, KURTZ.

Warren's Geography, BREWER.

IDDINGS, Joseph Paxton. On a group of volcanic rocks from the Tewan Mountains, New Mexico, and on the occurrence of primary quartz in certain basalts. U. S. Geol. Survey, Bull. No. 66, pp. 34.

Abstract, Am. Jour. Sci., 3d series, vol. 41, pp. 248–249, ½ p. 1891.

Petrographic description and discussion of the possible origin of porphyritic quartz.

—— The mineral composition and geological occurrence of certain igneous rocks in the Yellowstone National Park.

Washington Phil. Soc., Bull., vol. 11, pp 191–220, table.

Prefatory geologic sketch of the region; petrographic descriptions, chemical constituents and discussion of the variations in mineralogic composition and crystalline structure.

—— and **PENFIELD**, S. L. Fayalite in the Obsidian of Lipari.

Am. Jour. Sci., 3d series, vol. 40, pp. 75–78.

Abstract, Am. Naturalist, vol. 24, p. 1072, 7 lines.

Includes brief references to the containing and associated rocks.

Illinois. Artesian waters from drift, ROLFE.

Bowlder belts and bowlder trains, CHAMBERLIN.

Building stones, MERRILL, G. P.

Climate indicated by interglacial beds, LEVERETT.

Deep well at Dixon, TIFFANY.

Glacial boundary, WRIGHT.

Glacial phenomena, LEVERETT.

History of Niagara River, GILBERT.

Report—Division of Glacial Geology, U. S. Geol. Survey, CHAMBERLIN.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, CHAMBERLIN. WORTHEN. WRIGHT.

Indiana. Analyses of limestone, CLARKE. CATLETT.

Bowlder belts and bowlder trains, CHAMBERLIN.

Building stones, MERRILL, G. P.

Climate indicated by interglacial beds, LEVERETT.

History of Niagara River, GILBERT.

Glacial boundary, WRIGHT.

Keokuk beds, GORDON.

Origin of pressure of gas, ORTON. MCGEE.

Trenton limestone, oil, and gas, ORTON.

Petroleum belt at Terre Haute, WALDO.

Report—Division of Glacial Geology, U. S. Geol. Survey, CHAMBERLIN.

Digitized by Google

iana—Continued.
Macfarlane's Railway Guide, CHAMBERLIN. COLLETT. WRIGHT.
Warren's Geography, BREWER.
ian Territory. Coal Measures, CHANCE.
Explorations, HILL.
Macfarlane's Railway Guide, LOUGHRIDGE.
Warren's Geography, BREWER.
HALL, Elfric Drew. Report on mines d mining on Lake Superior.
Canada, Geol. Survey, Reports, vol. 3, new eries, part 2, Report H, pp. iv, 1–114, 125–31, pls. i–ix, map, 1888.
Abstract, Am. Geologist, vol. 5, p. 242, ½ p. Includes frequent incidental geologic descriptions and sections. Accompanied by colored map and section of Silver Mountain district.
a. Brecciated character of St. Louis limestone, GORDON.
Building stones, MERRILL, G. P.
Deep well at Le Mars, TODD.
Folding of Carboniferous in southwestern Iowa, TODD.
Lineage of Lake Agassiz, TODD.
Loess and its fossils, SHIMEK.
Loess about Muscatine, WITTER.
Macfarlane's Railway Guide, McGEE.
Makoqueta shales, JAMES.
Microscopic structure of oolite, BARBOUR.
Origin of extra-morainic till, TODD.
Report—Potomac Division, U. S. Geol. Survey, McGEE.
Terraces of the Missouri, TODD.
Topographic types of southeastern Iowa, McGEE.
Transitional drift, WEBSTER.
Warren's Geography, BREWER.

Iowa Academy of Sciences, Proceedings, 1887–1889.
Terraces of the Missouri, TODD.
Origin of extra-morainic till, TODD.
Loess about Muscatine, WITTER.
Crowley's Ridge, Arkansas, CALL.
Lineage of Lake Agassiz, TODD.
Folding of Carboniferous, TODD.
Crystalline rocks of Missouri, HAWORTH.
Eastern Arkansas, CALL.
Keokuk beds at Keokuk, GORDON.

Iowa State University Laboratories of Natural History, Bulletin, vol. 1, Nos. 2–4, vol. 2, No. 1.
Loess and its fossils, SHIMEK.

[**IRELAN**, William, jr.] California cement.
California, Ninth Report of Mineralogist, pp. 309–311.
Analyses of certain calcareous deposits from San Diego and Los Angeles counties and near Port Costa.

IRVING, R. D. Report—Lake Superior Division.
U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 132–141, 1889.
Includes a brief account of results of studies in Huronian region in Canada and the Marquette iron region; of the rocks at the falls of the Menominee, by G. H. Williams; and in the Mesabe Range and at Pigeon Point, by Bayley.

—— Explanatory and historical note.
U. S. Geol. Survey, Bull., No. 62. The greenstone schist areas of the Menominee and Marquette regions of Michigan, by G. H. Williams, pp. 11–30, pls. 1–2.
Review of previous observers, and discussion of geologic structure and relations of the region, especially in connection with the results of Williams's studies. Illustrated by two colored geologic maps.

J.

ES, Joseph F. On Laurentian as lied to a Quaternary terrane.
m. Geologist, vol. 5, pp. 29–35.
History of the use of the term with quotas from various writers to illustrate its application.

On the Maquoketa shales, and their elation with the Cincinnati group outhwestern Ohio.
m. Geologist, vol. 5, pp. 335–356, 394.
omprises an account of their stratigraphy, logic relations, fauna, and distribution,

JAMES, Joseph F.—Continued.
and a discussion of their extent and stratigraphic equivalency.
—— On the name "Laurentian."
Am. Geologist, vol. 6, pp. 133–134, ½ p.
Reply to Hitchcock in regard to its derivation, spelling and status as a geologic term.
—— Section of the Makoqueta [Maquoketa] shales in Iowa [abstract].
Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 250–251.
List of strata exposed in railroad cuts near Graf station.

Digitized by Google

JAMES, Joseph F.—Continued.

A cave in the Clinton formation of Ohio.

Cincinnati Soc. Nat. Hist., Jour., vol. 13, pp. 31-32.

Description of the cave and brief reference to the distribution and characteristics of the Clinton formation in Ohio.

JANIN, Louis, jr. Mulatos gold mines, State of Sonora, Mexico.

Engineering and Mining Jour., vol. 49, pp. 131-132. 4°.

Brief account of geology of the vicinity.

Johns Hopkins University Circulars, Nos. 78–84.

Expedition into southern Maryland and Virginia, CLARK.

Excursion in northern Appalachian region, WILLIAMS, G. H.

Gay Head, Massachusetts, CLARK.

JOHNSON, Lawrence C. Report—Lower Mississippi division.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 110-111, 1889.

Includes a brief allusion to a section exhibiting the Grand Gulf-Vicksburg contact in Wayne County, Mississippi.

[——] Florida.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 392-394.

General notes on the geology of the State and geological notes for railway stations.

JOHNSON, W. D. Clays.

California, Ninth Report of Mineralogist, pp. 287-308.

Includes several brief references to clay localities and analyses of eleven samples.

JUKES-BROWNE, A. J. The date of the high continental elevation of America.

Geol. Magazine, decade III, vol. 7, pp. 561-562.

Discussion of the evidence in the Caribbean region.

Jura-Trias.

Canada, Yukon district, DAWSON, G. M.

Lower Liard River, MCCONNELL.

Triassic traps of Nova Scotia, MARSTERS.

New Brunswick, BAILEY.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, DAWSON, G. M.

Central America, Nicaragua, CRAWFORD.

Geologic map of Mexico, CASTILLO.

Newark formation (Connecticut to North Carolina).

Jura-Trias—Continued.

Building stones, MERRILL, G. P.

North American Mesozoic, WHITE, C. A.

Use of terms Laurentian and Newark, HITCHCOCK.

Archean axes of eastern North America, DANA.

Boring in Trias at New Haven, HUBBARD.

Traps of East Haven-Brantford region, HOVEY, E. O.

Fillings in fissures in trap near Meriden, DAVIS.

Decay of rocks and origin of red color, DANA.

Relations of traps of Newark system, DARTON.

Intrusive origin of Watchung traps, New Jersey, NASON.

Studies of Triassic rocks of New Jersey, NASON.

Artesian wells, New Jersey, NASON.

Pseudomorphs at Paterson, New Jersey, HUNT, J. H.

Rivers of northern New Jersey, DAVIS.

Ancient shore lines, MERRILL, F. J. H.

Long Island Sound in Quaternary, DANA.

Topographic development of New Jersey, DAVIS and WOOD.

Tracks in York County, Pennsylvania, WANNER.

Analysis of sandstone from Maryland, CLARKE, F. W.

Triassic flora of Richmond, Virginia, MARCOU.

Notes on Richmond coal field, CLIFFORD.

Conglomerates in North Carolina, HOLMES, J. A.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, CAMPBELL. CHANCE. CROSBY. DARTON. HITCHCOCK. LESLEY. ROGERS. SMOCK. UHLER.

Western United States, North American Mesozoic, WHITE, C. A.

Permian of Texas, CUMMINS.

Review of Texas geology, DUMBLE.

Introduction, southwestern Kansas, MCGEE.

Digitized by Google

ura-Trias—Continued.
Kansas salt mine, HAY.
Southwestern Kansas, HAY.
Triassic flora of Richmond, Virginia, MARCOU.
Movements in Rocky Mountains, EMMONS.
Extinct volcanoes in Colorado, LAKES.
Macfarlane's Railway Guide, BAILEY. CONDON. DUTTON. ELDRIDGE.
Jura-Trias—Continued.
EMMONS. HAGUE. PUMPELLY. SCOTT. ST. JOHN. UPHAM.
Spanish Peaks region, HILLS.
Displacements in Grand Cañon, WALCOTT.
Warren's Geography, BREWER.
Nomenclature, Use of terms Laurentian and Newark, HITCHCOCK.
Triassic flora of Richmond, Virginia, MARCOU.

K.

nsas, Artesian wells, HAY.
Building stones, MERRILL, G. P.
Chalk from Niobrara Cretaceous, WILLISTON.
Cheyenne sandstone, CRAGIN.
Loess and its fossils, SHIMEK.
Lignite in Dakota formation, HAY.
Permo-Carboniferous of Greenwood and Butler counties, WOOSTER.
Macfarlane's Railway Guide, ST. JOHN.
Southwestern Kansas, HAY. MCGEE.
Salt mine, HAY.
Silverdale limestone, analysis, CATLETT.
Warren's Geography, BREWER.

nsas Academy of Sciences, Transactions, vol. 12, part 1.
Artesian wells in Kansas, HAY.

MP, J. F. On the dikes near Kennebunkport, Maine.
Am. Geologist, vol. 5, pp. 129–140.
Abstract, Geol. Soc. Am., Bull., vol. 1, pp. 31–32. (By author.)
Geologic relations, petrography, and ages.

Notes on a nepheline-basalt from ilot Knob, Texas.
Am. Geologist, vol. 6, pp. 292–294.
Abstract, Am. Naturalist vol. 24, p. 1189, 3 lines.
Petrography. Chemical analyses.

[Notice of supposed dikes in Devonian shales near Ithaca, New York.]
Geol. Soc. Am., Bull., vol. 1, p. 534, ½ p.

NNEDY, William. The central basin Tennessee. A study of erosion.
Canadian Inst., Proc., vol. 7, pp. 28, 64–108. 889.
Description of the physiography and geology of the region and discussion of its geologic history and topographic development and of erosion in general.

KENNEDY, William.—Continued.

KENTUCKY. Analysis of metamorphic rock from Marion County, EAKINS.
Building stones, MERRILL, G. P.
Macfarlane's Railway Guide, PROCTOR, WHITE. I. C. WRIGHT.
Middlesborough, BOYD.
Glacial boundary, WRIGHT.
Oil field of Barren County, FISCHER.
Orange sands and gravels, PROCTER.
Pits and domes of Mammoth Cave, HOVEY, H. C.
Preglacial channels at Falls of the Ohio, BRYSON.
Relations of flora to geology in Lincoln County, EVANS.
Vivianite near Eadsville, DUDLEY.
Wetwoods, BRYSON.
Warren's Geography, BREWER.

KIMBALL, James P. Siderite basins of the Hudson River epoch.
Am. Jour. Sci., 3d series, vol. 40, pp. 155–160, pl. 6.
Geologic relations, structure, and genesis of certain deposits in Columbia County, New York.

KNOWLTON, Frank Hall. Fossil wood and lignite of the Potomac formation.
U. S. Geol. Survey, Bull. No. 56, pp. 72, pls. 7. 1889.
Includes a brief sketch (pp. 38–41) of the distribution of the formation from various authorities, and an account of the modes of occurrence of the organic remains.

[KURTZ, M. A.] [Record of well at Nampa, Idaho.]
Boston Soc. Nat. Hist., Proc., vol. 27, pp. 425–426, ½ p.
List of beds penetrated to a depth of 320 feet.

Digitized by Google

L.

LADD, G. E. Notes on the building stones, clays, and sands of iron, St. Francois and Madison counties, Missouri.

Missouri, Geol. Survey, Bull. No. 1, pp. 22–44.

Brief descriptions of quarries.

—— The clay, stone, and sand industries of St. Louis city and county.

Missouri, Geol. Survey, Bull. No. 3, pp. 5–84, pls., maps.

Sketch of general geology, description of quarries, and analyses.

[LAFLAMME, J. C. K.] [Report on observations on north side of the St. Lawrence above Quebec.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 27–28. 1888.

Brief reference to occurrence of limestone bands, surface deposits of clay and dip of Trenton limestones.

LAKES, Arthur. Extinct volcanoes in Colorado.

Am. Geologist, vol. 5, pp. 38–43, pls. 2.

Description of crater and recent volcanic products near Dotsero station, preceded by brief accounts of the relations of various older lava flows in Colorado and recent ones in New Mexico.

LANGDON, Daniel W., jr. Geology of Mon Louis Island, Mobile Bay.

Am. Jour. Sci., 3d series, vol. 40, pp. 237–238.

Notice of a fossiliferous stratum and of an overlying sand series of supposed Appomattox age.

LAWSON, Andrew C. Report on the geology of the Rainy Lake region.

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report F, pp. 182, map, pls. 1–7.

Abstracts, Am. Geologist, vol. 5, pp. 55–56. Am. Naturalist, vol. 24, pp. 170–171, ½ p.; Geol. Magazine, decade 3, vol. 7, pp. 36–39.

Description of structure, distribution and petrography of the various crystalline rock series and discussion of their structural relations, stratigraphy, age, history, and equivalency. Brief chapter on glacial phenomena, post-glacial deposits, and economic geology.

—— Notes on the pre-Paleozoic surface of the Archean terranes of Canada.

Geol. Soc. Am., Bull., vol. 1, pp. 133–173.

Abstracts, Am. Geologist, vol. 5, p. 119, ½ p. Am. Naturalist, vol. 24, p. 208, ½ p.

Account of the irregularities of contour of pre-Paleozoic floor in various regions and brief discussion of the persistence of these irregularities after the erosion of the Paleozoics; former extension of the Paleozoics; overlaps due to transgressions and oscillations in level; erosion of the Archean, and source of Paleozoic sediments. Discussed by J. W. Spencer.

LAWSON, Andrew C.—Continued.

—— Note on the mapping of the Archean northeast of Lake Superior. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 245–246, ½ p.

Brief notice of components and relations of upper and lower Archean.

—— Note on the occurrence of native copper in the Animikie rocks of Thunder Bay.

Am. Geologist, vol. 5, pp. 174–178.

Geologic relations and petrographic characteristics of containing rocks.

—— [Petrographic descriptions of Huronian and Laurentian rocks from north of Lake Huron.]

Am. Geologist, vol. 6, pp. 30–32.

Abstract, Am. Naturalist, vol. 24, p. 1072, 6 lines.

—— and **SHUTT**, F. T. Petrograpical differentiation of certain dikes of the Rainy Lake region.

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 246–247, ½ p.

Discussion of structural, mineralogical, and chemical variations in different parts of the same dike.

LEDOUX, Albert R. The phosphate beds of Florida.

New York Acad. Sci., Trans., vol. 9, pp. 84–94.

Engineering and Mining Jour., vol. 49, pp. 175–177. 4°.

Sci. Am. Supt., vol. 30, pp. 12104–12105, No. 758. 4°.

Includes incidental accounts of geologic relations and a brief sketch of geology of Florida, quoted from E. A. Smith's papers.

LEIDY, Joseph. Notice and description of fossils in caves and crevices of the limestone rocks of Pennsylvania.

Pennsylvania, Geol. Survey, Report for 1887, pp. 1–20, pls. 1, 2.

Includes a brief description of cave in Lower Helderberg limestone near Stroudsburg.

LERCH, Otto, **CUMMINS**, W. F., and. A geological survey of the Concho country, State of Texas.

Am. Geologist, vol. 5, pp. 321–335, map.

Physiography, Pleistocene, Cretaceous, and Permian formations. Economic geology.

LESLEY, J. P. Pennsylvania.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 151–175.

Geologic notes for railway stations.

LEVERETT, Frank. Changes of climate indicated by interglacial beds and attendant oxidation and leaching.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 455–459.

Digitized by Google

LEVERETT, Frank—Continued.

Abstracts. Am. Geologist, vol. 5, p. 123, 7 lines. Am. Naturalist, vol. 25, p. 279, 1-6 p. 1891.

Discussion of the bearing of various lines of evidence, especially that furnished by recent studies in Ohio, Indiana and Illinois.

—— Glacial studies bearing on the antiquity of man. [Abstract.]

Boston Soc. Nat. Hist., Proc., vol. 27, pp. 585–586.

Discussion of bearing of evidence afforded by moraines and post-moraine deposits.

—— Glacial phenomena of northeastern Illinois and northern Indiana. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, p. 248, ½ p.

Moraine structure and history.

[**LEWIS**, H. C.] [Note for vicinity of Blackville, Pennsylvania.]

Macfarlane's Geol. Railway Guide, 2d edition, p. 172, 5 lines.

LINDGREN, W. Petrographical notes from Baja California, Mexico.

California Acad. Sci., Proc., vol. 2, pp. 1–17.

Descriptions of granites, diorites, quartz-porphyrites, basalt, slates, and diabases, with incidental references to their occurrence, relations, and age.

[**LINDSEY**, James G.] [Notes for central New York.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 134–135.

Stations on West Shore railway, Esopus to Albany.

Liverpool Geological Association Journal, vol. 9.

Evolution of Grand Cañon of the Colorado, HEWITT.

Liverpool Literary and Philosophical Society, Proceedings, vol. 41.

Lake Lahontan, MCLINTOCK.

[**LOUGHRIDGE**, R. H.] Arkansas [in part], Indian Territory and Texas.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 407–413.

Geological notes for railway stations.

Louisiana, Analysis of marble, HILLEBRAND.

Appomattox formation, MCGEE.

Macfarlane's Railway Guide, HILGARD.

Saliferous deposits as evidence of climatal conditions, SHALER.

Warren's Geography, BREWER.

LOW, A. P. Report on explorations in James Bay and country east of Hudson Bay drained by Big, Great Whale, and Clearwater Rivers.

Canada, Geol. Survey, Reports, vol. 3, new series, part 2, report J, pp. 1–62, 1888.

Abstract, *Ibid.*, part 1, report A, pp. 19–21 Am. Geologist, vol. 5, pp. 242–243, ½ p.

Itinerary accounts of geology and list of glacial striæ.

—— [Report on explorations of the eastern coasts, islands, and rivers of Hudson Bay.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 80–82. 1888.

Includes a brief reference to the nature of the rocks of the region and to the occurrence of bowlders.

—— The Mistassini region.

Ottawa Naturalist, vol. 4, pp. 11–28.

With several brief references to geologic features.

LYMAN, Benjamin Smith. Report on the New Boston and Morea coal lands in Schuylkill County, Pennsylvania.

Pennsylvania, Geol. Survey, Report for 1887, pp. 37–91, map in pocket.

Stratigraphy and structure.

M.

McCONNELL, R. G. Glacial features of parts of the Yukon and Mackenzie rivers.

Geol. Soc. Am., Bull., vol. 1, pp. 540–544.

Abstracts, Am. Geologist, vol. 5, p. 119, ½ p. Am. Naturalist, vol. 24, p. 208, ½ p.

Topographic features, alluvial and glacial deposits, direction of ice flow, terraces, glacial history, and incidental reference to Archean, Devonian, and Cretaceous formations.

—— [Letter on explorations on the lower part of Liard River.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 12–13. 1888.

McCONNELL, R. G.—Continued.

Includes a brief reference to occurrence of Devonian, Triassic and Cretaceous rocks.

McCREERY, J. M. Notes on some of the causes of extinction of species.

Am. Geologist, vol. 5, pp. 100–104.

Reviews the stratigraphic distribution of several Silurian species in Ohio.

[**McCUTCHEN**, A. R.] Georgia.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 374–377.

Revision and new notes for railway stations.

Digitized by Google

MACFARLANE, James. An American geological railway guide, giving the geological formation at every railway station, with altitudes above mean tide water, notes on interesting places on the routes and a description of each formation. Second edition, revised and enlarged. Edited by James R. Macfarlane, 426 pages, New York.

The revisions and enlargements contributed by Bailey, G. E., Broadhead, Campbell, J. L. and H. D., Chamberlin, Chance, Chester, Collett, Condon, Cooper, Crosby, Dana, J. D., Darton, Davis, Dawson, G. M., Dutton, Dwight, Emmons, Fontaine, Ford, Frazer, Gilbert, Hague, Hall, C. W., Hammond, Hastings, Hilgard, Hitchcock, Hunt, T. S., Johnson, L. C., Lesley, Lewis, H. C., Lindsey, Loughridge, McCutchen, McGee, Orton, Owen, Parsons, Proctor, Pumpelly, Putnam, Rogers, St. John, Safford, Scott, Smith and Gesner, Smock, Todd, Turner, Uhler, Upham, White, I. C., Williams, G. H., Williams, H. S., Willis, Winchell, A., Winchell, N. H., Worthen, and Wright.

McGEE, W J. The southern extension of the Appomattox formation.

Am. Jour. Sci., 3d series, vol. 40, pp. 15–41.

Abstract, Geol. Soc. Am., Bull., vol. 1, pp. 546–547, 548–549 (by author), with discussion by C. H. Hitchcock, C. D. Walcott, W. M. Davis, and J. Hall, pp. 548, 549 ½ p. Other abstracts, Am. Geologist, vol. 5, p. 120, ½ p; Am. Naturalist, vol. 24, p. 209, ½ p.

Distribution, characteristics, relations, and history from North Carolina to Mississippi, with brief references to associated Columbia and Tertiary formations. Taxonomy. Exposition of methods of classification and correlation by "homogeny," illustrated by the formations of the coastal plain of the Atlantic slope.

—— Report—Potomac division of geology.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 102–110.

Includes brief statements regarding the Pleistocene history of northeastern Iowa.

—— Introduction.

U. S. Geol. Survey, Bull. No. 57, A geological reconnaissance in southwestern Kansas, by Robert Hay, pp. 11–14.

Review of the problems presented in the Great Plains region.

—— Topographic types of northeastern Iowa. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 248–249.

The abstract consists of brief descriptions of the various types and of the history recorded in the topography and associated deposits. Incidentally there is postulated a new law of water carving.

McGEE, W J.—Continued.

—— Encroachments of the sea.

The Forum, vol. 10, pp. 437–449.

Review of evidences of coastal subsidence of eastern North America.

—— [Remarks on pressure of rock gas, especially in Indiana.]

Geol. Soc. Am., Bull., vol. 1, pp. 96–97, ½ p.

In discussion of memoir by Edward Orton on "origin of rock pressure of natural gas."

—— [Remarks on the extent of an early Pleistocene submergence of the Atlantic coast.]

Geol. Soc. Am., Bull., vol. 1, p. 409, ½ p.

Reference to amount of submergence in South Carolina, and to the Columbian deposits to which it gave rise in the southeastern United States.

—— [Remarks on the formations comprised under the term "orange sand," and on the relations of certain loams and gravels in the vicinity of Vicksburg and Grand Gulf.]

Geol. Soc. Am., Bull., vol. 1, pp. 474–475.

In discussion of paper by T. C. Chamberlin on "Some additional evidence bearing on the interval between the glacial epochs."

—— [Remarks on the relations of the Pleistocene deposits at Belvidere on the Delaware.]

Geol. Soc. Am., Bull., vol. 1, p. 480, ½ p.

Brief reference to relations of Columbia terraces and the terminal moraine.

—— [Remarks on certain peculiarities of drainage in the southeastern United States.]

Geol. Soc. Am., Bull., vol. 1, pp. 548–549.

Calls attention to drainage systems having the same location in successive geologic times from late Eocene to the present, and suggests a designation for this class of drainage

—— Geology for 1887 and 1888.

Smithsonian Instn., Report, 1888, (part 1), pp. 217–260.

An account of the principal contributions to North American geology, with a prefatory account of the institutions promoting geology.

—— Iowa.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 233–245.

Brief sketch of the geology of Iowa and geological notes for railway stations.

McINNES, William, **BAILEY**, L. W., and. Report on exploration and surveys in portions of northern New Brunswick and adjacents areas in Quebec and Maine, U. S.

Digitized by Google

INNES, William, BAILEY, L. W., and—Continued.

Canada, Geol. Survey, Reports, vol. 3, new series, part 2, report M, p. 52. 1888.

Abstracts, Ibid, part 1, report A, pp. 35–37; Am. Geologist, vol. 5, pp. 246–247, ¾ p.; Am. Jour. Sci., 3d series, vol. 39, p. 239, 4 lines.

The Silurian formation; its distribution, structure, stratigraphy, paleontology, the age, correlation, and extent of its various members, and evidence of internal unconformity.

—— [Account of explorations in northern New Brunswick.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, report A, pp. 91–93, 1888.

Notes relating to the Silurian formation.

KELLAR, Peter. On potholes north of Lake Superior unconnected with existing streams.

Geol. Soc. Am., Bull., vol. 1, pp. 568–570.

Abstract, Am. Naturalist, vol. 24, pp. 292–293, ¾ p.

Description of the holes, and allusions to the schists in which they lie, topographic characteristics of region, date of currents by which they were produced, and existence of terraces in their vicinity.

LINTOCK, R. Lake Lahontan, an extinct Quaternary lake of northwest Nevada, U. S. A.

Liverpool Lit. and Phil. Soc., Proc., vol, 41, pp. 339–342.

Abstract of I. C. Russell's U.S. Geol. Survey, Monograph, vol. 11.

Line. Archean axes of eastern North America, DANA.

Classification of glacial sediments of Maine, STONE.

Building stones, MERRILL, G. P.

Eastern Maine and New Brunswick, BAILEY.

Macfarlane's Railway Guide, HITCHCOCK.

Northern New Brunswick, BAILEY and McINNES.

Investigations in New Brunswick, BAILEY.

Mount Desert Island, SHALER.

Report on coast line geology, U. S. Geol. Survey, SHALER.

Silurian graptolites, DODGE.

Trap dikes near Kennebunkport, KEMP.

Warren's Geography, BREWER.

Rochester Geological Society, Transactions, vol. 20, parts 9–17.

Richmond coal field, CLIFFORD.

Salt deposits of America, WARD, T.

MARCOU, Jules. Reply to the questions of Mr. Selwyn on "Canadian geological classification for Quebec."

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 357–364.

In regard to the nature of the rocks at the falls of the Montmorenci, the age of the sandstones of the strait of Belle Isle, and the relations in the Quebec region.

—— The Triassic flora of Richmond, Virginia.

Am. Geologist, vol. 5, pp. 160–174.

Historical descriptions and review of literature from 1834 to 1889, and discussion of paleontologic evidence as to age of the Jura Trias of the United States.

—— The American Neocomian and the Gryphæa Pitcheri.

Am. Geologist, vol. 5, pp. 315–317.

Review of R. T. Hill's "A preliminary annotated check list of the Cretaceous invertebrate fossils of Texas," Texas Geol. Survey, Bull. No. 4.

In regard to discovery and nomenclature of the lower Cretaceous.

—— The lower and middle Taconic of Europe and North America.

Am. Geologist, vol. 5, pp. 357–375; vol. 6, pp. 78–102, 221–233.

A general review of certain questions relating to stratigraphy, distribution, general relations, taxonomy, and nomenclature of the lower Silurian and Cambrian formations.

—— Use of the terms Laurentian and Champlain in geology.

Am. Geologist, vol. 6, pp. 63–65.

History of the terms and discussion of their status.

MARSH, O. C. The skull of the gigantic Ceratopsidæ.

Geol. Magazine, decade III, vol. 7, pp. 1–5, pl. 1.

Includes brief prefatory remarks on the geology of the "Ceratops" beds.

—— Division of vertebrate paleontology.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 114–115. 1889.

Includes brief reference to subdivisions in the great Miocene basin of Dakota and evidence of vertebrate remains on the age of the Potomac formation.

MARSTERS, V. F. Triassic traps of Nova Scotia, with notes on other "intrusives" of Pictou and Antigonish counties, Nova Scotia.

Am. Geologist, vol. 5, pp. 140–145.

Geologic relations, petrography, and evidences of extrusive nature of the more prominent trap masses in the Triassic and Carboniferous areas.

Digitized by Google

Maryland. Analyses of rocks from Baltimore County, CHATARD. WHITFIELD, J. E.
Analysis of Triassic sandstone, CLARKE, F. W.
Analyses of dolomite from Cockeysville, WHITFIELD, J. E.
Building stones, MERRILL, G. P.
Expedition in southern Maryland and Virginia, CLARK, W. B.
Fossil wood of Potomac formation, KNOWLTON.
Gabbros of Delaware, CHESTER.
Macfarlane's Railway Guide, FONTAINE. UHLER. WILLIAMS, G. H. CHESTER.
Non-feldspathic intrusives, WILLIAMS, G. H.
Potomac flora, FONTAINE.
Report—Division of Paleobotany, U. S. Geol. Survey, WARD, L. F.
Report—Division of vertebrate Paleontology, U. S. Geol. Survey, MARSH.
Warren's Geography, BREWER.
Wright's "Ice age in North America," HITCHCOCK.

Massachusetts. Analyses of sands and clay, Martha's Vineyard, CLARKE, F. W. RIGGS.
Archean axes of eastern North America, DANA.
Bernardston, series of upper Devonian, EMERSON. DANA.
Building stone, MERRILL, G. P.
Cretaceous plants, Martha's Vineyard, WHITE, D. NEWBERRY.
Cretaceous fossils, Martha's Vineyard, SHALER.
Evidence of till on glacial climate, CROSBY.
Essex County, SEARS.
Excursion in northern Appalachians, WILLIAMS, G. H.
Gay Head, CLARK, W. B. MERRILL, F. J. H. WARD, L. F.
Granitoid areas in lower Laurentian, HITCHCOCK.
Granites in Massachusetts, EMERSON.
Kaolin in Blanford, CROSBY.
History of Boston Basin, CROSBY.
Macfarlane's Railway Guide, CROSBY. UPHAM.
Ottrelite and ilmenite schists, WOLFF.

Massachusetts—Continued.
Metamorphic phenomena, EMERSON.
Report—Division of Archean geology, U. S. Geol. Survey, PUMPELLY.
Report—Atlantic coast division, U. S. Geol. Survey [shore lines, Cretaceous, metamorphic rocks], SHALER.
Report—Division of coast line geology, U. S. Geol. Survey, SHALER.
Report—Division Paleozoic invertebrates, U. S. Geol. Survey, WALCOTT.
Sanborn bowlder, SCOVILLE.
Taconic mountains, AM. GEOLOGIST.
Tertiary and Cretaceous deposits, SHALER.
Vein filling in till, EMERSON.
Warren's Geography, BREWER.

MARTIN, Daniel S. The origin of diagonal trends in the earth's crust, with application to the production of normal and reversed faults and the folding of strata. [Abstract.]
New York Acad. Sci., Trans., vol. 9, pp. 15–21.
A general discussion.

—— A note on the colored clays recently exposed in railroad cuttings near Morrisania, New York.
New York Acad. Sci., Trans., vol. 9, p. 46, ½ p.
Decription of an exposure exhibiting highly colored clays.

—— [Clay outlier near Monmouth Junction, New Jersey.]
New York Acad. Sci., Trans., vol. 9, p. 83, ½ p.
Reference to a small area of supposed Cretaceous age. Discussed by N. L. Britton, p. 88, 2 lines.

MATTHEW, G. F. On Cambrian organisms in Acadia.
Canada, Roy. Soc., Trans., vol. 7, section IV, pp. 135–162, pls. v–ix.
Abstract, Canadian Record of Science, vol. 3, pp. 383–387. 1889.
With prefatory remarks on the stratigraphy and equivalency of the basal series, (pp. 135–143).

—— Eozoon and other low organisms in Laurentian rocks at St. John.
New Brunswick, Nat. Hist. Soc., Bull., vol. 9, pp. 36–41.
Includes references to their modes of occurrence and the relations of the containing rocks.

Digitized by Google

MATTHEW, G. F.—Continued.

— On the occurrence of sponges in Laurentian rocks at St. John, N. B.

New Brunswick, Nat. Hist. Soc., Bull., vol. 9, pp. 42–45.

Includes brief supplemental portion on the stratigraphy and equivalency of the rocks and their associates.

— How is the Cambrian divided? A plea for the classification of Salter and Hicks.

Canadian Record of Science, vol. 3, pp. 475–485. 1889.

From the Am. Geologist, 1889, and described in the Bibliography for 1887 to 1889.

MERRILL, Frederick J. H. On the metamorphic strata of southeastern New York.

Am. Jour. Sci., 3d series, vol. 39, pp. 383–392.

Classification and characteristics of the several belts and discussion of relations, extent, age, and equivalency.

— A note on the colored clays recently exposed in railroad cuttings near Morrisania, New York.

New York Acad. Sci., Trans., vol. 9, pp. 45, 46, ½ p.

Description of their relations and allusions to the history of the associated superficial deposits.

— Some ancient shore-lines and their history.

New York Acad. Sci., Trans., vol. 9, pp. 78–83.

Review of the evidence and history of Triassic to post-Quaternary orographic movements in the middle Atlantic coast region. Discussed by D. S. Martin and N. L. Britton, p. 83, ½ p.

— Barrier beaches of the Atlantic coast.

Popular Science Monthly, vol. 37, pp. 736–745.

Includes a discussion of the origin and history of the New Jersey beaches and brief reference to some of those of Florida.

— [Remarks regarding the interglacial deposits of the Delaware.]

Geol. Soc. Am., Bull., vol. 1, p. 477, ½ p.

Brief allusions to their relations, distribution, and equivalence, especially at Belvidere.

— [Remarks on the stratigraphy and structure of Gay Head.]

Geol. Soc. Am., Bull., vol. 1, p. 556, ½ p.

Am. Naturalist, vol. 24, pp. 563, 564.

Briefly discusses age, history, and relations of the several formations.

MERRILL, George P. The collection of building and ornamental stones in the U. S. National Museum. A handbook and catalogue.

Smithsonian Inst., Report for 1886, part 2, pp. 277–648, pls. 1–9. 1889.

Includes brief descriptions of principal quarries and stones of the United States and reference to notable foreign localites, and a short chapter on physical and chemical properties of rocks, illustrated by a plate of thin sections of the following: Granite, Hallowell, Maine; oolitic limestones, Caldwell County, Kentucky; marble, Rutland, Vermont; diabase, Weehawken, New Jersey; sandstones, Portland, Connecticut, and Potsdam, New York.

—— Petrography for 1887 and 1888.

Smithsonian Inst., Report, 1888, (part 1), pp. 327–354.

Bibliography of lithological publications and account of contributions on physical and chemical conditions of crystallization, contact metamorphism, dynamic metamorphism, and some other general subjects.

—— [Preliminary notes on eruptive rocks collected about Fort Ellis and in Gallatin Valley, Montana.]

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 147, 148. 1889.

Given by A. C. Peale, Report, Montana Division of geology.

—— Notes on the serpentinous rocks of Essex County, New York, from aqueduct shaft 26, New York City, and from near Easton, Pennsylvania.

U. S. Nat. Museum, Proc., vol. 12, pp. 595–600.

Mineralogic.

Mexico. Corals and reefs of western Gulf of Mexico, HEILPRIN.

Division of Mesozoic invertebrate paleontology, U. S. Geol. Survey, WHITE, C. A.

Geological map, CASTILLO.

Macfarlane's Railway Guide, CHANCE. MACFARLANE. FRAZER.

Mulatos gold mines, Sonora, JANIN.

Petrographical notes from Baja California, LINDGREN.

MEYER, Abraham. Notes on the presence of Umbral or Mountain limestone in Lycoming County, Pennsylvania.

Philadelphia, Acad. Nat. Sciences, Proc., 1889, pp. 310, 311.

Description of outcrops on Hogelan Run and Loyalsock Creek.

Digitized by Google

MEZGER, A. The ore deposits and mines of Minas Geraes, Brazil.

Engineering and Mining Jour., vol. 50, pp. 238, 272, 273. 4°.

With incidental references to nature of the containing formations.

Michigan. Analysis of novaculite from Marquette, HILLEBRAND.

Analysis of porphyry from Pigeon Point, EAKINS.

Analyses of rocks collected by Irving, HILLEBRAND.

Analyses of rocks from Penokee-Gogebic range, CHATARD.

Building stones, MERRILL, G. P.

Copper mining district, ENG. AND MINING JOURNAL.

Distribution of bowlders, WINCHELL, A.

History of Niagara River, GILBERT.

Macfarlane's Railway Guide, WINCHELL, A.

Report—Lake Superior division, U. S. Geol. Survey, IRVING.

Greenstone schists, Marquette and Menominee region, WILLIAMS, G. H. IRVING.

Warren's Geography, BREWER.

Origin of basins of the Great Lakes, SPENCER.

MILLER, S. A. North American geology and paleontology for the use of amateurs, students, and scientists, pp. 664, Cincinnati.

Reviewed by J. D. Dana, Am. Jour. Sci., 3d series, vol. 39, p. 67, ½ p.

Includes a prefatory general account of North American geology.

MILLS, J. E. [Remarks on the history of Lake Winnepeg-Mississippi drainage.]

Geol. Soc. Am., Bull., vol. 1, p. 407, ½ p.

In discussion of paper by J. B. Tyrrell on "Post-Tertiary deposits of Manitoba."

Minnesota. Analysis of brick clay, New Ulm, CHATARD.

Analyses of rocks from Menominee River, RIGGS.

Analyses of rocks from Pigeon Point, RIGGS. HILLEBRAND. WHITFIELD, J. E.

Building stones, MERRILL, G. P.

Deserted gorge near Minnehaha Falls, GRANT.

Geological Survey, report for 1888 reviewed, DANA.

Minnesota—Continued.

Lineage of Lake Agassiz, TODD.

Loess and its fossils, SHIMEK.

Macfarlane's Railway Guide, HALL, C. W. UPHAM. WINCHELL, N. H.

Origin of rocks, Pigeon Point, BAYLEY.

Origin of Keewatin ores, WINCHELL, N. H. and H. V.

Position of Ogishke conglomerate, WINCHELL, A.

Relation of rocks on Pigeon Point, BAYLEY.

Report on Rainy Lake region, LAWSON.

Results of Archean studies, WINCHELL, A.

Taconic iron ores of Minnesota and New England, WINCHELL, N. H. and H. V.

Warren's Geography, BREWER.

MINOR, Francis. Evidences of glacial action in Virginia.

Popular Science Monthly, vol. 37, p. 551, ½ col.

Calls attention to occurrence of certain bowlders in Orange County, Virginia.

Mississippi. Appomattox formation, MCGEE.

Macfarlane's Railway Guide, HILGARD.

Report—Lower Mississippi division, U. S. Geol. Survey, JOHNSON, L. C.

Orange sand formations, MCGEE.

Sandstone dikes, DILLER.

Peculiarities in drainage, MCGEE.

Warren's Geography, BREWER.

Missouri. Bibliography of geology, SAMPSON.

Brecciated character of St. Louis limestone, GORDON.

Building stones, clays, and sands, LADD. MERRILL, G. P.

Coal beds of La Fayette County, WINSLOW.

Crinoids from Burlington limestone, ROWLEY.

Crystalline rocks of Missouri, HAWORTH.

Glacial boundary, WRIGHT.

Iron ores of the United States, HUNT, T. S.

Lineage of Lake Agassiz, TODD.

Macfarlane's Railway Guide, BROADHEAD.

Digitized by Google

issouri—Continued.
Tallow clays, SEAMON.
Warren's Geography, BREWER.
Zinciferous clays, SEAMON.
issouri Geological Survey, Bulletin No. 1.
Coal of La Fayette County, WINSLOW.
Building stones, LADD.
—— No. 2.
Bibliography of zoology of Missouri, SAMPSON.
—— No. 3.
Clay, stone, lime, and sand of St. Louis region, LADD.
ontana. Analyses of rocks, CHATARD and EAKINS. CHATARD. CATLETT. EAKINS.
Montana—Continued.
Crazy Mountains, WOLFF.
Macfarlane's Railway Guide, DAWSON, G. M. PUMPELLY. PUTNAM. UPHAM.
Notes on rocks from Fort Ellis and Gallatin Valley, MERRILL, G. P.
Remains in Laramie, CANNON.
Laramie group, WARD, L.
Report—Montana division, U. S. Geol. Survey, PEALE.
Warren's Geography, BREWER.
MURCHISON, R. L. On the Silurian system of rocks.
Am. Geologist, vol. 5, pp. 80–83.
From London and Edinburgh Phil. Mag., 3d series, July, 1835.

N.

ASON, Frank L. On the intrusive origin of the Watchung traps of New Jersey. [Abstract.]
Geol. Soc. Am., Bull., vol. 1, pp. 562, 563, ¾ p.
Abstract, Am. Naturalist, vol. 24, p. 212, ½ p.
Discusses bearing of occurrence of trap conglomerates along western border of the Newark formation.
— Scapolite rock.
Am. Jour. Sci., 3d series, vol. 39, p. 407, 6 lines.
Notice of an occurrence in northern New Jersey.
— Geological studies of the Archean rocks.
New Jersey, Geol. Survey, report for 1889, pp. 12–65, 1889.
Historical review of surveys in the Archean highlands. Faulted structure. Type rocks and their distribution. Building stones. Molybdinite, zircon, and graphite.
—] Geological studies of the Triassic or red sandstone rocks.
New Jersey Geol. Survey, Report, 1889, pp. 66–72, 1889.
Discussion of origin of trap pebbles in the conglomerates and general statements in regard to the structure of the formation and the history of its eruptive rocks.
—?] Artesian wells.
New Jersey Geol. Survey, Report for 1889, pp. 82–89.
Records of recent well-borings in various parts of the State.
— and FERRIER, Walter F. A notice of some zircon rocks in the Archean highlands of New Jersey. [Abstract.]
NASON, Frank L., and FERRIER, Walter L.—Continued.
Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 244–245.
Includes remarks on mineralogic constituents of the rock and evidence of its intrusive nature.
National Geographic Magazine, vol. 2.
Rivers of northern New Jersey, DAVIS, W. M.
Nebraska, Lineage of Lake Agassiz, TODD.
Loess and its fossils, SHIMEK.
Macfarlane's Railway Guide, TODD.
Warren's Geography, BREWER.
NEFF, Peter. The Sylvania sand in Cuyahoga County, Ohio.
Geol. Soc. Am., Bull., vol. 1, pp. 32–34.
Abstract, Am. Naturalist, vol. 24, p. 110, 4 lines.
Reviews evidence of well records as to its distribution, characteristics and stratigraphic relations.
Nevada, Analysis of adobe soil, EAKINS.
Macfarlane's Railway Guide, HAGUE.
Natural soda, CHATARD.
Warren's Geography, BREWER.
NEWBERRY, John Strong. The Paleozoic fishes of North America, U. S. Geol. Survey, Monograph, vol. 16, 340 pages, 53 pls.
Includes a brief reference to Devonian and Carboniferous stratigraphy in general, mainly in connection with the occurrence of fish remains.

Digitized by Google

NEWBERRY, John Strong—Cont'd.

—— The Laramie group. Its geologic relation, its economic importance, and its fauna and flora.

New York Acad. Sci., Trans., vol. 9, pp. 27–32.

Abstract (by author). Geol. Soc. Am., Bull., vol. 1, pp. 524–527, 527–528, with discussion by J. B. Tyrrell, L. F. Ward, J. J. Stevenson, and E. D. Cope, pp. 527–532.

Other abstracts, Am. Geologist, vol. 5, p. 118, ½ p. Am. Naturalist, vol. 24, pp. 856–857, ½ p.

Discussion of its stratigraphic position and the relations and equivalency of its component formations in different regions.

—— The rock-salt deposits of the Salina group in western New York. [Abstract.]

New York Acad. Sci., Trans., vol. 9, pp. 39–45.

Includes an account of their geology, and records of several bored wells.

—— [Remarks on the northern extension and equivalency of the Amboy clays.]

Geol. Soc. Am., Bull., vol. 1, p. 455, ½ p.

In discussion of paper by D. White on "Cretaceous plants from Martha's Vineyard."

New Brunswick Natural History Society, Bulletin, vol. 9.

Organisms in Laurentian at St. John, MATTHEW.

Sponges in Laurentian rocks at St. John, MATTHEW.

New Hampshire, Archean axes of eastern North America, DANA.

Granitoid areas in lower Laurentian, HITCHCOCK.

Building stones, MERRILL, G. P.

Macfarlane's Railway Guide, HITCHCOCK.

Report—Division of coast-line geology, U. S. Geol. Survey, SHALER.

Madison bowlder, CROSBY.

Studies of hornblende schist, HITCHCOCK.

Warren's Geography, BREWER.

New Jersey, Analyses of serpentine, CATLETT.

Ancient shore lines, MERRILL.

Amboy clays, NEWBERRY.

Artesian wells, NASON.

Artesian wells, Atlantic City, WOOLMAN.

Barrier beaches, MERRILL, F. J. H.

New Jersey—Continued.

Building stones, MERRILL, G. P.

Clay at Monmouth Junction, BRITTON, MARTIN.

Cretaceous plants, Martha's Vineyard, WHITE, D.

Encroachments of the sea, MCGEE.

Excursion in northern Appalachians, WILLIAMS, G. H.

Fiords and great lake basins of North America, UPHAM.

Glacial boundary, WRIGHT.

Glacial studies bearing on the antiquity of man, LEVERETT.

Glacial deposits at Belvidere, MCGEE. MERRILL, F. J. H.

Intrusive origin of Watchung traps, NASON.

Macfarlane's Railway Guide, DARTON. SMOCK.

Metamorphic strata of southeastern New York, MERRILL, F. J. H.

Potomac flora, FONTAINE.

Pseudomorphs at Paterson, HUNT, J. H.

Rivers of northern New Jersey, DAVIS.

Report—Division of Cenozoic invertebrates, U. S. Geol. Survey, DALL.

Scapolite rock, NASON.

Studies of Archean rocks, NASON.

Studies of Triassic rocks, NASON.

Traps of Newark system, DARTON.

Topographic development of northern New Jersey, DAVIS and WOOD.

Warren's Geography, BREWER.

Wright's "Ice age in North America."

Zircon rocks in Archean highlands, NASON and FERRIER.

New Jersey Geological Survey, Annual Report for 1889.

Studies of Archean rocks, NASON.

Triassic rocks, NASON.

Artesian wells, NASON.

New Mexico, Analysis of adobe soil, EAKINS.

Analysis of [eruptive] rocks, EAKINS.

Colorado group, STEVENSON.

Cretaceous and northern Mexico, WHITE, C. A.

Drainage systems, TARR.

Extinct volcanoes of Colorado, LAKES.

Digitized by Google

w Mexico—Continued.
Laramie group, COPE. NEWBERRY. WARD, L.
Lower Cretaceous of San Carlos mountains, WHITE, C. A.
Macfarlane's Railway Guide, DUTTON.
Movements in Rocky Mountains, EMMONS.
Plications of Coal Measures, VAN DIEST.
Volcanic rocks from Tewan mountains, IDDINGS.
Warren's Geography, BREWER.

w York, Analysis of dolomite from Westchester County, HILLEBRAND.
Analyses of inclusions in diorite at Crugers, CHATARD.
Analyses of serpentines, CATLETT.
Amboy clays, NEWBERRY.
Ancient shore lines, MERRILL, F. J. H.
Building stones, MERRILL, G. P.
Calciferous in Champlain Valley, BRAINERD and SEELY.
Clays near Morrisiana, MARTIN, MERRILL, F. J. H.
Cuboides zone, WILLIAMS, H. S.
Deformation of Iroquois beach, SPENCER.
Excursion in northern Appalachians, WILLIAMS, G. H.
Extensions of the Iroquois beach, SPENCER.
Fiords and great lake basins of North America, UPHAM.
Fossils in eastern part of Dutchess County, DWIGHT.
Fossils at Pleasant Valley, DWIGHT.
Fossils in Taconic belt at Hillsdale, DANA.
Glacial boundary, WRIGHT.
Glacial geology, Irondequoit region, DRYER.
History of Niagara River, GILBERT.
Iron mines, SMOCK.
Iron ores, HUNT, J. S.
Iroquois beach, DAVIS, SPENCER.
Lake ridges of Ohio, WRIGHT.
Long Island Sound in Quaternary and submerged Hudson River channel, DANA.
Macfarlane's Railway Guide, DANA. DARTON. DWIGHT. FORD, HITCHCOCK, J. M. HUNT, T. S. LINDSEY. SMOCK. WILLIAMS, H. S.
Mastodon at Attica, CLARKE, J. M.

New York—Continued.
Middle Taconic at Stissing, DWIGHT.
Origin of Syracuse serpentine, WILLIAMS, G. H.
Pot-holes opposite Catskill, HUBBARD.
Report on oil and gas, CARLL.
Report—Paleozoic division of paleontology, U. S. Geol. Survey, WALCOTT.
Report—Division of Paleozoic invertebrates, U. S. Geol. Survey, WALCOTT.
Report—Atlantic coast division, U. S. Geol. Survey [shore lines on Catskill mountains], SHALER.
Richfield Springs clay, analysis, CATLETT.
Rock salt deposits, NEWBERRY.
Saliferous deposits as evidence of climatal conditions, SHALER.
Sandstone in drift on Staten Island, GRATACAP.
Serpentinous rocks, MERRILL, G. P.
Siderite basins, KIMBALL.
Silurian fossils, Columbia County, BISHOP.
Structure of Devonian and Silurian in west central New York, PROSSER, C. S.
Supposed dikes at Ithaca, KEMP.
Traps of Newark system, DARTON.
Unconformity in Hudson valley, DAVIS.
Value of term "Hudson River group," WALCOTT.
Warren's Geography, BREWER.
Wright's "Ice age in North America," HITCHCOCK.

New York Academy of Sciences, Transactions, vol 9.
Salt deposits western New York, NEWBERRY.
Clays at Morrisania, New York, MERRILL, F. J. H., MARTIN.
Ancient shore lines, MERRILL, F. J. H.
Clay at Monmouth Junction, New Jersey, MARTIN.
Phosphate beds of Florida, LEDOUX.
Jottings on the Nile and in the desert, BOLTON.
Pseudomorphs at Paterson, New Jersey, HUNT, J. H.
——, **vol. 10, Nos. 1-3.**
Geology of the Bahamas, NORTHRUP.

Digitized by Google

New York, Commissioners of the State Reservation at Niagara, 6th report.
History of the Niagara River, GILBERT.

New York State Museum, Bulletin, No. 7. Iron ores of New York, SMOCK.

New York State Museum, 41st annual report.
Mastodon at Attica, CLARKE, J. M.

———, 42d annual report.
Hercynian question, CLARKE, J. M.
Record of locality numbers, HALL.

New Zealand. Analysis of geyserite. WHITFIELD, J. E.

North Carolina. Appomattox formation, MCGEE.
Cape Fear River region, CLARK.
Iron ores, HUNT, T. S.
Mesozoic conglomerates, HOLMES, J. A.
Triassic flora of Richmond, Virginia, MARCOU.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, CHANCE.

NORTHRUP, John I. Notes on the geology of the Bahamas.

New York Acad. Sci., Trans., vol. 10, pp. 4–22.

O.

Ohio. Analyses of limestones, CATLETT. WHITFIELD, J. E.
Analyses of sandstones, EAKINS. CLARKE, F. W.
Bowlder belts and bowlder trains, CHAMBERLIN.
Building stones, MERRILL, G. P.
Cave in Clinton formation, JAMES.
Climate indicated by interglacial bed, LEVERETT.
Glacial boundary, CHAMBERLIN. WRIGHT.
History of Niagara River, GILBERT.
Lake ridge of Ohio, WRIGHT.
Geological Survey report, ORTON.
Macfarlane's Railway Guide, CHAMBERLIN. ORTON. WHITE, I. C. WRIGHT.
Origin of pressure of gas, ORTON.
Portsmouth sandstones, analyses, CHATARD.
Pre-glacial channels at Falls of the Ohio, BRYSON.
Pre-glacial drainage of western Pennsylvania, FOSHAY.
Report on oil and gas, CARLL.
Some causes of extinction of species, MCCREERY.
Sylvania sand in Cuyahoga County, NEFF.
Trenton limestone oil and gas, ORTON.
Waverly group, COOPER, W. F.
Warren's Geography, BREWER.

Ohio, Geological Survey. First annual report, ORTON.

Oregon. Natural soda, CHATARD.
Macfarlane's Railway Guide, CONDON. DAWSON, G. M. HASTINGS.
Paleontology of the northwest coast, DALL.
Report—Division of volcanic geology, U. S. Geol. Survey, DUTTON.
Sandstone dikes, DILLER.
Silver Lake, COPE.
Warren's Geography, BREWER.

ORTON, Edward. The Trenton limestone as a source of petroleum and inflammable gas in Ohio and Indiana.

U. S. Geol. Survey, 8th Report, J. W. Powell, pp. 475–662, pls. LIV–LX, 1889.
Abstracts, Am. Naturalist, vol. 24, pp. 661–663; Am. Geologist, vol. 5, pp. 388–391.
Discussion of the origin and modes of accumulation of oil and gas. Description of the stratigraphy and rock structure of the region and an account of the practical development of the oil and gas fields. Illustrated by colored geologic maps and sections.

—— On the origin of the rock pressure of natural gas of the Trenton limestone of Ohio and Indiana.

Am. Jour. Sci., 3d series, vol. 39, pp. 225–229.
Statement of conditions and discussion of the nature and cause of the pressure.

—— Origin of the rock pressure of natural gas in the Trenton limestone of Ohio and Indiana.

Geol. Soc. Am., Bull., vol. 1, pp. 87–94, 96.
Abstracts, Am. Geologist, vol. 5, p. 119, ½ p; Am. Naturalist, vol. 24, p. 955, 4 lines.
This paper differs from the one on the same

Digitized by Google

RTON, Edward—Continued.

subject in Am. Jour. Sci., vol. 39, in consisting of a more extended discussion of the several theories, the laws of gas production, and the duration of the gas supply. Discussed by I. C. White, W J McGee, and A. C. Lawson, pp. 94–97.

— Geological survey of Ohio (third organization), first annual report, x, 323 pages, 2 maps in pocket. Columbus.

Mainly covering the oil and gas fields, with a prefatory general sketch of the geology of the State, a review of theories of the origin and accumulation of gas and oil a discussion of laws that govern their distribution, and a description of the fault in Adams County. Accompanied by two maps of oil fields.

ORTON, Edward—Continued.

—— Ohio.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 177–187.

Revision of table of geological formations of the State and geological notes for railway stations.

Ottawa Naturalist, vol. 3, No. 4.

Geological progress in Canada, ELLS.

———, vol. 4, Nos. 1–9.

Mistassini region, LOW.

Serpentines of Canada, GIROUX.

OWEN, Richard. Arkansas [in part].

Macfarlane's Geol. Railway Guide, 2d edition, pp. 406, 407.

Geological notes for railway stations.

P.

ACKARD, A. S. An attempt to explain glacial lunoid furrows.

Am. Geologist, vol. 5, pp. 104–106.

Description of some instances in Switzerland and New England and discussion of their origin.

ALMER, Charles S. A preliminary paper on the eruptive rocks of Boulder County and adjoining counties, Colorado.

Colorado Sci. Soc., Proc., vol. 3, pp. 230–236.

Brief reference to geologic formations and structural relations and petrographic notes concerning the various eruptives.

ARSONS, James.] West Virginia Central and Plattsburg Railway.

Macfarlane's Geol. Railway Guide, 2d edition, p. 347, ½ p.

Geological notes for the stations.

ALE, A. C. Report—Montana division of geology.

U. S. Geol. Survey, 8th Report, J. W. Powell, pp. 146–148, 1889.

Brief accounts of the extension of lake beds westward to Madison Valley, and to the occurrence and extent of certain eruptive rocks near Fort Ellis and in the southwestern part of the Gallatin Valley, with petrographic description by G. P. Merrill.

Report—Montana division of geology.

U. S. Geol. Survey, 9th Report, J. W. Powell, pp. 111–114, 1889.

Brief summary of results of observations in Gallatin and Jefferson River regions.

nsylvania. Analysis of serpentine. CATLETT.

Building stones, MERRILL, G. P.

Casts of flattened scolithus, WANNER.

Pennsylvania—Continued.

Clay in Northumberland County, analysis, CATLETT.

Diatoms from river clays of Philadelphia, WOOLMAN.

Fossil in caves in limestone, LIEDY.

Fractured strata in Bedford County, STEVENSON.

Glacial boundary, CHAMBERLIN. WRIGHT.

Glacial phenomena in the Beaver Valley, FOSHAY and HICE.

History of Niagara River, GILBERT.

History of glacial deposits of Ohio Valley, WHITE, I. C.

Iron ores, HUNT, T. S.

Making of Pennsylvania, CLAYPOLE.

Macfarlane's Railway Guide, LESLEY. LEWIS, H. C. WHITE, I. C.

Microscopic structure of oolite, BARBOUR.

Origin of pressure of gas, WHITE, I. C.

Pre-glacial drainage of western Pennsylvania, FOSHAY.

Report on New Boston and Morea coal lands, LYMAN.

Report on oil and gas, CARLL.

Serpentines of southeastern Pennsylvania, RAND.

Serpentine rocks near Easton, MERRILL, G. P.

State line serpentines, CHESTER.

Tracks in Trias of York County, WANNER.

Traps of Newark system, DARTON.

Umbral limestone in Lycoming County, MEYER.

Digitized by Google

Pennsylvania—Continued.
Warren's Geography, BREWER.
Wright's "Ice age in North America," HITCHCOCK.

Pennsylvania Geological Survey, Annual report for 1887.
Cave fossils, LEIDY.
Fossil tracks in Trias, WANNER.
New Boston coal basin, LYMAN.
State line serpentines, CHESTER.

Pennsylvania Geological Survey.
Seventh report on oil and gas fields, CARLL.

PENFIELD, S. L., **IDDINGS**, Joseph P. and. Fayalite in the obsidian of Lipari.
Am. Jour. Sci., 3d series, vol. 40, pp. 75–78. Abstract, Am. Naturalist, vol. 24, p. 1072, 7 lines.
Includes brief references to the containing rocks and their associates.

PENROSE, R. A. F. A preliminary report on the geology of the Gulf tertiaries of Texas from Red River to the Rio Grande.
Texas, Geol. Survey, First Annual Report, pp. 3–101.
Stratigraphy, structural relations and distribution of Tertiary and post-Tertiary deposits, pp. 3–64. Economic geology, pp. 65–101.

Petrography, Huronian and Laurentian north of Lake Huron, BARLOW. LAWSON.
Archean of central Canada, LAWSON.
Building stones of the United States, MERRILL, G. P.
Eruptives of Lake Huron region, FAIRBANKS.
Rocks of Thunder Bay district, BAYLEY.
Copper in Animikie at Thunder Bay, LAWSON.
Origin of soda granite, etc., Pigeon Point, BAYLEY.
Greenstone schists, Michigan, WILLIAMS, G. H.
Certain dikes of Rainy Lake region, LAWSON and SHUTT.
Report on Rainy Lake region, LAWSON.
Notes on Big Bend of the Columbia, COLEMAN.
Granitoid areas in lower Laurentian, HITCHCOCK.
Bernardston series of upper Devonian, EMERSON.

Petography—Continued.
Rocks of Essex County, Massachusetts, LEWIS.
Granites of Massachusetts, EMERSON.
Crystalline rocks of Missouri, HAWORTH.
Pre-Cambrian of the Black Hills, VAN HISE.
Geology of Cape Ann, SHALER.
Metamorphic strata of southeastern New York, MERRILL, F. J. H.
Archean rocks, New Jersey, NASON.
Zircon rocks in highlands of New Jersey, NASON and FERRIER.
Non feldspathic intrusives of Maryland, WILLIAMS, G. H.
Traps of Newark system in New Jersey region, DARTON.
Syracuse serpentines, WILLIAMS, G. H.
Serpentinous rocks, New York and Pennsylvania, MERRILL, G. P.
Serpentines of southeastern Pennsylvania, RAND.
Lithology of rocks from Yukon district, ADAMS.
Structure of oolite, BARBOUR.
Trenton limestone, Ohio and Indiana, ORTON.
Trap dikes near Kennebunkport, Maine, KEMP.
Triassic traps of Nova Scotia, MARSTERS.
Dikes in Appalachian Virginia, DILLER.
Notes from Baja California, Mexico, LINDGREN.
Rocks from Montana, MERRILL, G. P.
Eruptive rocks of Boulder County, Colorado, PALMER.
Volcanic rocks from Tewan Mountains, New Mexico, IDDINGS.
Igneous rocks of Yellowstone Park, IDDINGS.
Fayalite in obsidian of Lipari, IDDINGS and PENFIELD.
Basalt from Pilot Knob, Texas, KEMP.
Origin of gneiss, BELL.
Observations in Norway, WILLIAMS, G. H.
Report—Division of Petrography, U. S. Geol. Survey, DILLER.
Secondary minerals of amphibole and pyroxene groups, CROSS.
Petrography for 1887 and 1888.

Digitized by Google

ladelphia, Academy of Natural Sciences, Proceedings, 1889, part 3.
Umbral limestone in Lycoming County, Pennsylvania, MEYER.
Drift on Block Island, RAND.
———, 1890, parts 1, 2.
Serpentines of southeastern Pennsylvania, RAND.
Artesian wells at Atlantic City, New Jersey, WOOLMAN.
Diatoms in clays of Philadelphia, WOOLMAN.
Vincelonian volcano, SHARP.
Coral and coral reefs of western Gulf of Mexico, HEILPRIN.

istocene.
'aska, Surface geology, RUSSELL.
'antic coast region, Classification of glacial sediments of Maine, STONE.
History of Boston basin, CROSBY.
Glacial sand plains, DAVIS.
Tertiary and Cretaceous of Massachusetts, SHALER.
Glacial lunoid furrows, PACKARD.
Cape Ann, Massachusetts, SHALER.
Bernardston series, EMERSON.
Mount Desert Island, SHALER.
Sanborn bowlder, Massachusetts, SAVILLE.
Distribution of bowlders, HITCHCOCK.
Kaolin in Blandford, Massachusetts, CROSBY.
Gay Head, MERRILL, F. J. H.
Glacial scratches near Norfolk, Connecticut, CORNISH.
Vein filling in till of Connecticut Valley, EMERSON.
Drift on Block Island, RAND.
Evidence of till on glacial climate, CROSBY.
Division of coast line geology, U. S. Geol. Survey, SHALER.
Magnetite and sea water in drift, ROBERTSON.
Report—Atlantic coast division, U. S. Geol. Survey, SHALER.
Madison bowlder, CROSBY.
Glacial action in southeastern Connecticut, WELLS.
Long Island Sound and submerged channel of the Hudson, DANA.
Pot-holes opposite Catskill, New York, HUBBARD.

Pleistocene—Continued.
Clays near Morrisania, New York, MERRILL, F. J. H.
Sandstone in drift on Staten Island, GRATACAP.
Ancient shore lines, MERRILL, F. J. H.
Topographic development of New Jersey, DAVIS and WOOD.
Wright's "Ice Age in North America," HITCHCOCK.
Rivers of Northern New Jersey, DAVIS.
Artesian wells, New Jersey, NASON.
Fiords and great lake basins of North America, UPHAM.
Deposits on the Delaware, MCGEE. MERRILL, F. J. H.
Barrier beaches, MERRILL, F. J. H.
Report—Atlantic coast division, U. S. Geol. Survey, SHALER.
Encroachment of the sea, THOMPSON. MCGEE.
Diatoms from river clays at Philadelphia, WOOLMAN.
Potomac flora, FONTAINE.
Southern Maryland and Virginia, CLARK.
Southern extension of Appomattox formation, MCGEE.
Topography of Florida, SHALER. AGASSIZ.
Analyses of coquina and coral rock, Florida, CLARKE, F. W.
Pleistocene submergence, MCGEE. SPENCER. SHALER.
Report—Atlantic coast division, U. S. Geol. Survey, Florida, SHALER.
Extent of submergence of Atlantic coast, MCGEE.
Continental elevation of America. BROWNE.
Southern drift in Georgia, SPENCER.
Warren's Geography, BREWER.
Mon Louis Island, Mobile Bay, LANGDON.
Date of high continental elevation of America, BROWNE.
Macfarlane's Railway Guide, CHAMBERLIN. CHANCE. CHESTER. CROSBY. FONTAINE. GESNER. HAMMOND. HITCHCOCK. JOHNSON. LESLEY. LEWIS, H. C. SMITH, E. A. SMOCK. UHLER. UPHAM.

Digitized by Google

Pleistocene—Continued.

Appalachians to Mississippi basin, Glacial phenomena of northern Illinois and Indiana, LEVERETT.

Climate indicated by interglacial beds, LEVERETT.

Deep well at Dixon, Illinois, TIFFANY.

Central basin of Tennessee, KENNEDY.

Orange sand formations, MCGEE. PROCTER.

Vivianite, Kentucky, DUDLEY.

Wetwoods, BRYSON.

Ice age in North America, DAVIS.

History of upper Ohio region, WHITE, I. C.

Pre-glacial drainage of western Pennsylvania, FOSHAY.

Pre-glacial channels at Falls of the Ohio, BRYSON.

Glacial phenomena in Beaver Valley, FOSHAY and HICE.

A recent rock-flexure [in Wisconsin], CRAMER.

Interval between glacial epochs, CHAMBERLIN.

Glacial sand plains, DAVIS.

Bowlder belt and bowlder trains, CHAMBERLIN.

Distribution of bowlders, WINCHELL, A. WRIGHT.

Report—Division of glacial geology, U. S. Geol. Survey, CHAMBERLIN.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, CAMPBELL. CHAMBERLIN. COLLETT. LESLEY. ORTON. PROCTOR. SAFFORD. WHITE, I. C. WINCHELL, A. WORTHEN. WRIGHT.

Central America. About the Nicaragua footprints, CRAWFORD. FLINT.

Geologic map of Mexico. CASTILLO.

Submergence of Isthmus of Panama, UPHAM.

General. Growth, culmination and departure of ice sheets. UPHAM.

Interval between glacial epochs. CHAMBERLIN.

Cause of the glacial period, UPHAM. CHAMBERLIN.

Quaternary changes of level, UPHAM.

Glacial climate, CROSBY. SHALER. UPHAM.

Extent of glaciers, CHAMBERLIN.

Pleistocene—Continued.

Glacial studies bearing on the antiquity of man, LEVERETT.

Continental elevation preceding the Pleistocene, SPENCER.

Pleistocene flora of Canada, DAWSON, J. W.

Glacial phenomena, BELL. DWIGHT.

Use of terms Laurentian and Champlain, MARCOU. JAMES. HITCHCOCK.

Wright's "Ice age in North America," HITCHCOCK.

Great Lakes region and eastern Canada. History of Niagara River, GILBERT.

Iroquois beach, DAVIS. SPENCER.

Deformation of Iroquois beach, SPENCER.

Northeastern extension of the Iroquois beach, SPENCER.

General Pleistocene submergence, SPENCER.

Ancient shores in region of Great Lakes, SPENCER.

Origin of basins of the Great Lakes, SPENCER. BONNEY. HINDE. SELLEY.

Fiords and great lake basins of North America, UPHAM.

Lake St. John country, CHAMBERS.

Glacial geology, Irondequoit region, DRYER.

A moraine of recession in Ontario, WRIGHT.

Gravel deposits of Ontario, SPENCER.

Preglacial drainage of western Pennsylvania, FOSHAY.

Mastodon at Attica, New York, CLARKE, J. M.

Lake ridges of Ohio, WRIGHT.

Pot-holes north of Lake Superior, MCKELLAR.

Mines of Lake Superior, INGALL.

Geology of Ontario, BELL.

Geology of the northwest of Lake Superior, HARVEY.

Hudson Bay, LOW.

Glacial phenomena in the Beaver Valley, Pennsylvania, FOSHAY and HICE.

Northwestern Manitoba, TYRRELL.

Glaciation of eastern Canada, CHALMERS.

Surface geology, New Brunswick, CHALMERS.

Digitized by Google

Pleistocene—Continued.
Lake Temiscaming and Montreal River region, BELL.
Progress of investigations, New Brunswick, BAILEY.
Report on Quebec, ELLS. WALCOTT.
Pictou and Colchester Counties, Nova Scotia, FLETCHER.
Southern invertebrates on shores of Acadia, GANNONG.
St. Lawrence Valley, LAFLAMME.
Macfarlane's Railway Guide, CHAMBERLIN, DAWSON, G. M. HALL, C. W. WINCHELL, A.
Mississippi basin to Rocky Mountains.
Lineage of Lake Agassiz, TODD.
Origin of extra-morainic till, TODD.
Outlet of Lake Agassiz, CHAMBERLIN.
Terraces of the Missouri, TODD.
Sand of St. Louis County, LADD.
Brick clay, New Ulm, Minnesota, analysis, CHATARD.
Deserted gorge near Minnehaha falls, GRANT.
Lake Winnipeg, Mississippi drainage, MILLS.
Loess and its fossils, SHIMEK.
Report—Montana division, U. S. Geol. Survey, PEALE.
Artesian wells in Dakotas, UPHAM.
Southwestern Kansas, HAY.
Greenwood and Butler Counties, Kansas, WOOSTER.
Kansas salt mine, HAY.
Drift of northern Iowa, WEBSTER.
Report—Potomac division, U. S. Geol. Survey, MCGEE.
Topographic types, Iowa, MCGEE.
Loess at Muscatine, Iowa, WITTER.
Crowley's Ridge, Arkansas, CALL.
Staked Plains, Texas, HILL.
Eagle Flats formation, Texas, HILL.
Pilot Knob, Texas, HILL.
Indian Territory and Red River, HILL.
Valley of Upper Canadian, Texas, HILL.
Report on Gulf Tertiaries of Texas, PENROSE, R. A. F.
Central Texas, COMSTOCK. TARR.
Trans-Pecos Texas, STREERUWITZ.
Review of Texas geology, DUMBLE.
Eastern Colorado, CANNON.
Yellowstone Park, WEED.

Pleistocene—Continued.
Macfarlane's Railway Guide, BROADHEAD. CHAMBERLIN. ELDRIDGE. HALL, C. W. HILGARD. LOUGHRIDGE. MCGEE. OWEN. ST. JOHN. TODD. UPHAM. WINCHELL, N. H.
Warren's Geography, BREWER.
Rocky Mountains to Pacific Coast. Analysis of adobe soil, EAKINS.
Analyses of lavas, Arizona, EAKINS.
Lake Lahontan, MCLINTOCK.
Lake Bonneville, GILBERT.
Analyses of lavas from Lassen Peak, HILLEBRAND.
Analyses of volcanic rocks from California, CHATARD.
Protozootites, FRIEDRICH.
Analyses of rocks from northern California, EAKINS. WHITFIELD, J. E.
Analysis of lava from Shasta County, California, RIGGS.
Natural soda, CHATARD,
Macfarlane's Railway Guide, CONDON. COOPER. DALL. DAVIS. GILBERT. HAGUE. HASTINGS. PUMPELLY. WILLIS.
Analysis of clays from Owen's Lake, California, CHATARD.
Auriferous gravels of California, HAMMOND.
Mono Valley, California, RUSSELL.
Clays, JOHNSON, W. D.
Santa Clara County, California, WEBER.
Record of well at Nampa, Idaho, KURTZ.
Age of beds in Boisé River region, EMMONS. COPE.
Warren's Geography, BREWER.
Western Canada. Glaciation of northern Cordillera, DAWSON, G. M.
Post-Tertiary deposits of Manitoba, TYRRELL.
Duck and Riding Mountains, TYRRELL.
James Bay region, LOW.
Limits of glaciation in the Northwest, CHAMBERLIN.
Yukon and Mackenzie Rivers, MCCONNELL.
Yukon district, DAWSON, G. M.
Caribou district, British Columbia, BOWMAN.
Glaciation of Cordillera and Laurentide, CHALMERS.

Digitized by Google

Popular Science Monthly, 1890.
Glacial action in Virginia, MINOR.
Glacial action in southeastern Connecticut, WELLS.
Barrier beaches of the Atlantic coast, MERRILL, F. J. H.

PRESTON, E. B. Los Angeles County.
California, Ninth Report of Mineralogist, pp. 189–210.
Incidental references to geology at various points.

PROCTER, John R. [Remarks on the relations of Orange sands and certain gravels in the western Kentucky region.]
Geol. Soc. Am., Bull., vol. 1, pp. 476–477, ½ p.
Notes on relations and distribution in various parts of the region.

[——] Kentucky.
Macfarlane's Geol. Railway Guide, 2d edition, pp. 395–400.
Geological notes for railway stations.

PROSSER, Charles S. The thickness of the Devonian and Silurian rocks of western central New York.
Am. Geologist, vol. 6, pp. 199–211.

PROSSER, Charles S.—Continued.
Well records. General geologic section of the region. Review of previous estimates of thickness.

PUMPELLY, Raphael. Report—Division of Archean geology.
U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 124–125, 1889.
Includes a brief notice of certain results in the Hoosac Mountain region.

—— Report—Division of Archean geology.
U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 75–76, 1889.
Includes brief statement regarding stratigraphic relations and age of the formations in the Green Mountains.

[——] Northern Pacific Railroad.
Macfarlane's Geol. Railway Guide, 2d edition, pp. 259–262.
Geological notes for stations in western Dakota, Montana, and Idaho.

[**PUTNAM**, B. T.] Northern Pacific Railroad.
Macfarlane's Geol. Railway Guide, 2d edition, p. 261.
Geological notes for stations from Garrison to Missoula, Montana.

R.

RAND, Theodore D. Notes on the drift on Block Island.
Philadelphia Acad. Nat. Sci., Proc., 1889, pp. 408–409.
General description of topography and certain bluff exposures.

—— Notes on the genesis and horizon of the Serpentines of southeastern Pennsylvania.
Philadelphia Acad. Nat. Sci., Proc., 1890, pp. 76–123.
Comprised in a general description of their outcrops, structural relations, and associated rocks.

READE, T. Mellard—Origin of normal faults.
Am. Jour. Sci., 3d series, vol. 39, pp. 51–52.
Discussion of conditions involved in the development of normal faults mainly in review of Le Conte.

Rhode Island. Archean axes of eastern North America, DANA.
Drift on Block Island, RAND.
Ottrelite and ilmenite schists, WOLFF.
Warren's Geography, BREWER.

RICKETTS, Louis D. Annual report of the Territorial Geologist to the governor of Wyoming, January, 1890, 80 pages, 3 plates.
Consists mainly of descriptions of the coal fields, with brief reports on the iron ores and other minerals, the petroleum beds, soluble salt deposits, marbles, building stones, and the resources of the Black Hills in Crook County.

RIGGS, R. B. Twelve rocks from Menominee River, Michigan and Wisconsin. Analyses.
U. S. Geol. Survey, Bull., No. 55, p. 81, ½ p., 1889.

—— Rocks from Pigeon Point, Minnesota. Analyses.
U. S. Geol. Survey, Bull., No. 55, pp. 82–83, 1889.

—— [Lava from Shasta County, California. Analysis.]
U. S. Geol. Survey, Bull., No. 55, p. 84, ¼ p., 1889.

—— [Green sands, white sand, fossil

Digitized by Google

RIGGS, R. B.—Continued.

bones, and phosphatic nodules at Gay Head, Massachusetts.] [Analyses.]

U. S. Geol. Survey, Bull., No. 55, p. 90, ½ p., 1889.

—— Eruptive rock from Henry Mountains, Utah. [Analysis.]

U. S. Geol. Survey, Bull., No. 60, p. 154, ½ p.

—— Lavas from near Lassen Peak, California. [Analyses.]

U. S. Geol. Survey, Bull., No. 60, pp. 156, 157, ½ p.

—— **CLARKE**, F. W. and. Limestones from Ohio. [Analyses.]

U. S. Geol. Survey, Bull., No. 60, p. 160, ½ p. Trenton limestones and Utica shales.

ROBERTSON, Robert. [On distribution of magnetite and sea water in drift formations of New England.]

U. S. Geol. Survey, Eighth Report, J. W. Powell, p. 127, ½ p., 1889.

Referred to by N. S. Shaler in Report—Division of coast line geology.

ROGERS, William B. Virginia.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 352–358, 363.

Republished from 1st edition.

ROLFE, Charles W. Artesian water from the drift [in eastern Illinois].

Am. Geologist, vol. 6, pp. 32–35.

Description of surface relations and well borings in drift, and discussion of the source of the water supply and its relation to the structure of the sub-terrane.

ROWLEY, R. R. Some observations on

ROWLEY, R. R.—Continued.

natural casts of crinoids and blastoids from the Burlington limestone.

Am. Geologist, vol. 6, pp. 66, 67.

Includes brief reference to the components of the formation in Pike County, Missouri.

RUSSELL, Israel C. Quaternary history of Mono Valley, California.

U. S. Geol. Survey, 8th Report, J. W. Powell, pp. 261–394, pls. 16–44. 1889.

Abstracts. Am. Geologist, vol. 6, pp. 54–56; Am. Jour. Sci., 3d series, vol. 39, p. 402, ½ p.

Lacustral, glacial, and volcanic deposits, phenomena and history; and post-Quaternary orographic movements.

—— Notes on the surface geology of Alaska.

Geol. Soc. Am., Bull., vol. 1, pp. 99–154–155, pl. 2.

Abstracts, Am. Geologist, vol. 5, p. 118–119, ½ p.; Am. Naturalist, vol. 24, p. 208, 4 lines.

Physiography. Geology of the Yukon River. The tundra. Rock decomposition. Glaciation terraces. Lake Yukon. Existing glaciers. Discussed by N. S. Shaler and T. C. Chamberlin, pp. 155–156.

—— Ice cliffs on Kowah River, Alaska, observed by Lieutenant Cantwell.

Am. Geologist, vol. 6, pp. 49, 50.

Presenting a letter from J. C. Cantwell, which briefly describes the ice cliffs and discusses their nature and history.

RUTLEY, F. Composite spherulites in obsidian from Hot Springs, California.

Geol. Soc. Quart. Jour., vol. 46, pp. 423–427.

Abstract, Am. Naturalist, vol. 24, pp. 1188, 1189, 8 lines.

Discusses the origin of the spherulitic structure. Petrographic.

S.

[**SAFFORD**, James M.] Tennessee.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 401–405.

Geological notes for railway stations.

ST. JOHN, Orestes. Kansas.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 274–289.

Geological notes for railway stations.

SAMPSON, F. A. A bibliography of the geology of Missouri.

Missouri Geol. Survey, Bull., No. 2, 158, XVIII pages.

SAVILLE, M. H. The Sanborn bowlder.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 586–588.

SAVILLE, M. H.—Continued.

Description of the bowlder and discussion of its source and the condition under which it was transported.

School of Mines Quarterly, vol. 11, parts 2 to 4.

Geysers, WEED.

Science, vol. 15.

Nicaragua footprints, FLINT.

Fossil plants, British Columbia, DAWSON, J. W.

Nova Scotia Carboniferous conglomerate, GILPIN.

Southern invertebrates on shores Acadia, GANONG.

Digitized by Google

Science—Continued.

———, vol. 16.

Chalk from Kansas, WILLISTON. DAWSON, G. M.

Geology of Quebec, AMI. SELWYN. ELLS.

Hypothesis for encroachments of sea, THOMPSON, G.

SCOTT, William B. Geological and faunal relations of the Uinta formation.

The Mammalia of the Uinta formation. Am. Phil. Soc., Trans., vol. 16, (new series), pp. 461–470.

Abstract, Am. Naturalist, vol. 24, p. 470, ½ p.

Review of structural, stratigraphic, and paleontological evidence.

[——] [Notes in Wyoming and Idaho.]

Macfarlane's Geol. Railway Guide, 2d edition, p. 312.

Geological notes for stations on Union Pacific Railroad from Granger, Wyoming, to Squaw Creek, Idaho.

Scottish Geographical Magazine, vol. 6. Geological map of the world, BARTHOLOMEW.

SEAMON, W. H. Tallow clays.

Sci. Am. Supt., vol. 30, p. 12287, 1¼ col., No. 769, 4°., from Scientiæ Baccalaureus.

Abstract, School of Mines, Quart., vol. 11, p. 175, ½ p.

Analyses of 32 specimens from Missouri lead regions.

—— The zinciferous clays of southeast Missouri and a theory as to the growth of the calamine of that section.

Am. Jour. Sci., 3d series, vol. 39, pp. 38–42.

Conditions of occurrence, chemical composition, and relations to the zinc deposits.

SEELY, Henry M., **BRAINERD**, Ezra and. The Calciferous formations in the Champlain Valley.

Geol. Soc. Am., Bull., vol. 1, pp. 501–511.

Am. Mus. Nat. Hist., Bull., vol. 3, pp. 1–23.

Abstracts. Am. Geologist, vol. 5, p. 120, 7 lines; Am. Jour. Sci., 3d series, vol. 39, pp. 235–238; Am. Naturalist, vol. 24, p. 955, 6 lines.

Distribution, stratigraphy, detailed descriptions of sections, and correlation of Fort Cassin strata and members of Phillipsburg series.

[**SEELEY**, H. G.] [Remarks on the origin of the basins of the Great Lakes of America.]

Geol. Soc., Quart. Jour., vol. 46, p. 533, ½ p.

Discussion of paper by that title by J. W. Spencer.

SEARS, John H. The stratified rocks of Essex County.

Essex Inst., Bull., vol. 22, pp. 21–47.

Description of the more or less metamorphic rocks, including olenellus limestones, their petrography, distribution, relations, and associated eruptives.

SELWYN, Alfred R. C. Summary reports of the operations of the Geological Survey for the years 1887 and 1888.

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report A, pp. 117, 1888.

Includes extracts from reports of assistants as follows: G. M. Dawson in Yukon region and southern interior of British Columbia; R. G. McConnell on the lower Liard River; J. B. Tyrrell in Duck and Riding Mountains region and in northwestern Manitoba; A. P. Low in the Hudson Bay region; R. Bell in northwestern Quebec and adjoining regions; F. D. Adams in eastern townships of Quebec; R. W. Ells in southeastern Quebec; J. C. K. Laflamme on north side of the St. Lawrence above Quebec; L. W. Bailey and William McInnes in northern New Brunswick; R. Chalmers on surface geology of New Brunswick; J. F. Whiteaves on age of fossils collected by McConnell on Liard River; A. Bowman on seaboard British Columbia; H. Fletcher on Pictou and Colchester Counties, Nova Scotia, and E. R. Faribault on gold-bearing belt in Halifax County. Also a brief reference to rocks and relations at gold mine near Whitefish station. C. P. R. R. (p. 59).

—— Tracks of organic origin in rocks of the Animikie group.

Am. Jour. Sci., 3d series, vol. 39, pp. 145–147.

Prefatory to letter by G. F. Matthews in regard to the nature of the tracks. Statement of opinion in regard to age of containing rocks.

—— The geology of Quebec city.

Science, vol. 16, p. 359, 1¼ cols. 4°.

Brief review of relations and equivalency of the rocks at Quebec.

SHALER, N. S. Report—Division of coast-line geology.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 125–128. 1889.

Includes references to studies of elevated coast lines in Maine and New Hampshire and observations by Robert Roberteon on distribution of magnetic iron and salt water in the drift formations of New England.

—— The geology of the Island of Mount Desert, Maine.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 987–1061, pls. 64–76. 1889.

Abstract, Am. Geologist, vol. 6, pp. 197–198.

Digitized by Google

[ALER, N. S.—Continued.

Description of superficial deposits, granites, stratified rocks, and glacial phenomena, and discussion of evidence of glacial and postglacial subsidence and of the origin and physical history of the Mount Desert rocks. Illustrated by colored geologic maps.

- Report—Atlantic coast division.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 71–74. 1889.

Includes brief references to evidence of wave action at the peak of Wachusett, Massachusetts, and in the Catskill Mountains in New York; occurrence of Cretaceous fossils on Martha's Vineyard; metamorphism of Carboniferous beds in Rhode Island; causes of undulations of sandy deposits in lake district of Florida; proofs of periods of elevation and subsidence of Florida, and subdivisions of the metamorphic rocks west of Attleborough, Massachusetts.

- The geology of Cape Ann, Massachusetts.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 529–611, pls. 32–37. 1889.

Abstract, Am. Geologist, vol. 7, p. 201, ½ p. 1891.

General geologic and geographic relations of Cape Ann district; nature and distribution of drift deposits; amount of erosion during the glacial period; postglacial erosion, marine and atmospheric; recent changes of level; marshes; physical structure of bed rocks, dikes, joint planes, and general petrography. With colored geologic maps.

On the occurrence of fossils of the Cretaceous age on the island of Martha's Vineyard, Massachusetts.

Harvard Coll., Mus. Comp. Zool., Bull., vol. 6, pp. 89–97, pls. 1, 2. 1889.

Description of the relations of the fossiliferous beds.

[Remarks on conditions attending Pleistocene submergence on the Atlantic coast.]

Geol. Soc. Am., Bull., vol. 1, p. 409, ½ p.

Discussion of this submergence in connection with the cause of the last glacial period.

The topography of Florida.

Harvard Coll., Mus. Comp. Zool., Bull., vol. 16, pp. 139–156, pl.

Abstract, Am. Naturalist, vol. 24, p. 768, ½ p.

Sets forth a hypothesis of the origin of the Floridian peninsula and the West India islands and points out the probable structural similarity to the Cincinnati arch. Classifies the topographic features of the State and discusses their history in some regions. Describes the coral reefs on the southeastern coast, their effect on drainage, erosion, extent

SHALER, N. S.—Continued.

northward, and evidence of subsidence. Incidentally refers to origin of kames.

—— Tertiary and Cretaceous deposits of eastern Massachusetts.

Geol. Soc. Am., Bull., vol. 1, pp. 443–452, pl. 9.

Abstracts, Am. Geologist, vol. 5, p. 118, ½ p.; Am. Naturalist, vol. 24, p. 210 ½ p.; Science, vol. 15, p. 10, ½ col. 4°.

Discussion of structure and age of dislocations, ages of the various deposits and glacial origin of bowlder beds containing fragments of osseous conglomerate. Description and plate of detailed sections at Gay Head and from Vineyard Sound.

—— Note on glacial climate.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 460–465.

Abstract, Am. Geologist, vol. 5, p. 124, ½ p.

Discusses the southward extension of the glacial ice line along the Appalachians, the Rocky Mountains, and in Europe; evidences of glacial action afforded by certain high level gravel deposits in the mountains of Virginia; position of the glacial snow line in America; evidence that the southern United States were considerably elevated during the glacial period; rainfall during glacial period, and climate immediately preceding that period.

—— Note on the value of saliferous deposits as evidence of former climatal conditions.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 580–585.

Discussion of the conditions under which salt was deposited at various geologic times.

SHARP, Benjamin. An account of the Vincelonian volcano.

Philadelphia Acad. Nat. Sciences, Proc., 189, pp. 289–295, pl. 4.

On the island of St. Vincent, West Indies.

SHIMEK, B. The loess and its fossils.

Iowa Lab. of Nat. Hist., Bull., vol. 1, pp. 200–214, vol. 2, pp. 89–98.

Abstract, Am. Jour. Sci., 3d series, vol. 4, p. 72, ½ p., 1891.

Includes a discussion of the bearing of the paleontologic evidence as to the physical and climatic conditions under which the loess was deposited.

SHUTT, F. T., **LAWSON**, A. C. and. Petrographical differentiation of certain dikes of the Rainy Lake region. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 246–247, ½ p.

Discussion of structural, mineralogical, and chemical variations in different parts of the same dike.

Digitized by Google

Silurian.

Appalachian. (Maine to Alabama.)

Graptolites from northern Maine, DODGE.

Areas of continental progress in North America, DANA.

New Brunswick and Maine, BAILEY. BAILEY and MCINNES.

Geology of Mount Desert, SHALER.

Fauna of rocks at Fort Cassin, Vermont, WHITFIELD, R. P.

Eolian limestone, HITCHCOCK.

Calciferous in Champlain Valley, BRAINERD and SEELY.

Calciferous formations, WALCOTT.

Lower and middle Taconic, MARCOU.

Survey of Minnesota, 1888, Review, DANA.

Rocks of Essex County, Massachusetts, SEARS.

Iron ores of the United States, HUNT, T. S.

Taconic iron ores, WINCHELL, N. H. and H. V.

Report—Division of Archean geology, U S. Geol. Survey, PUMPELLY.

Studies of hornblende schist, HITCHCOCK.

Report—Division of Paleozoic invertebrates, U. S. Geol. Survey, WALCOTT.

Report—Paleozoic division of Paleontology, U. S Geol. Survey, WALCOTT.

Siderite basin of Hudson River epoch, KIMBALL.

Unconformity in the valley of the Hudson, DAVIS.

Saliferous deposits as evidence of climatal conditions, SHALER.

Iron mines of New York, SMOCK.

Rock salt deposits of western New York, NEWBERRY.

Metamorphic strata of southeastern New York, MERRILL, F. J. H.

Fossils in Dutchess County, New York, DWIGHT.

Fossils at Pleasant Valley, New York, DWIGHT.

Silurian fossils in Columbia County, New York, BISHOP.

Macfarlane's Railway Guide, CAMPBELL. CROSBY. DANA. DARTON. DWIGHT. FORD. FONTAINE. HITCHCOCK. HUNT, T. S. LESLEY. LINDSEY. MCCUTCHEN. SAFFORD. SMOCK. SMITH and GESNER. WILLIAMS, H. S.

Fossils in Hillsdale, New York, DANA.

Thickness of rocks in west central New York, PROSSER, C. S.

Analysis of dolomite from Westchester County, New York, HILLEBRAND.

Locality numbers, HALL.

Traps of Newark system in New Jersey, DARTON.

Making of Pennsylvania, CLAYPOLE.

Casts of scolithus, Pennsylvania, WANNER.

Fossils in caves in Pennsylvania, LEIDY.

Dikes in Appalachian Virginia, DARTON.

Middleborough, Kentucky, BOYD.

Oil field of Barren County, Kentucky, FISCHER.

Analyses of dolomite and clay, Morrisville, Alabama, HILLEBRAND.

Warren's geography, BREWER.

Central and Western States. Central Basin of Tennessee, KENNEDY.

Cave in Clinton formation of Ohio, JAMES.

Origin of pressure of gas in Trenton limestone, ORTON.

Geological Survey of Ohio, report, ORTON.

Causes of extinction of species, MCCREERY.

Analyses of limestones from Ohio and Indiana, CLARKE, F. W.

Areas of continental progress, DANA.

Sylvania sand in Ohio, NEFF.

Trenton limestone oil and gas, ORTON.

Petroleum at Terre Haute, Indiana, WALDO.

Artesian waters from drift, Illinois, ROLFE.

Deep well at Dixon, Illinois, TIFFANY.

Maquoketa shales in Iowa, JAMES.

Zinciferous clays of Missouri, SEAMON.

Building stones of Missouri, LADD.

Indian Territory and Red River, HILL.

Drainage of central Texas, TARR.

Carboniferous of central Texas, TARR.

Review of Texas geology, DUMBLE.

Digitized by Google

Silurian—Continued.
Central mineral region of Texas, COMSTOCK.
Extinct volcanoes of Colorado, LAKES.
Warren's geography, BREWER.
Macfarlane's Railway Guide, BROADHEAD. CHAMBERLIN. COLLETT. DAWSON, G. M. EMMONS. HAGUE. LOUGHRIDGE. McGEE. ORTON. PROCTER. SAFFORD. WINCHELL, A. WORTHEN.
Canada, Northern New Brunswick and Maine, BAILEY and McINNES.
Lake St. John country, CHAMBERS.
Acadian and St. Lawrence watershed, BAILEY.
Areas of continental progress, DANA.
Investigations in New Brunswick, BAILEY.
Geology of Ontario, BELL.
History of Quebec group, HUNT.
Report on Quebec, ELLS.
Review of Ells on geology of Quebec, WALCOTT.
Geology of Quebec City, AMI. ELLS. SELWYN.
Lower and middle Taconic, MARCOU.
St. Lawrence Valley, ELLS. LAFLAMME.
Geological classification for Quebec, MARCOU.
Quebec and Taconic, AM. GEOLOGIST.
Lake Temiscaming and Montreal River region, BELL.
Quebec group of Logan, DAWSON, J. W.
Stratigraphy of "Quebec group," ELLS.
Lower Helderberg of St. Helens Island, DEEKS.
Pre-Paleozoic surface of Canada, LAWSON.
Gas in eastern Ontario, ASHBURNER.
Fossil sponges from Little Metis, DAWSON, J. W.
Fossils from Manitoba, WHITEAVES.
Fossil plants from Mackenzie and Bow Rivers, DAWSON, J. W.
Caribou district, British Columbia, BOWMAN.
Yukon district, DAWSON, G. M.
Warren's Geography, BREWER.
Macfarlane's Railway Guide, DAWSON, G. M.

Silurian—Continued.
Nomenclature: Value of term "Hudson River group," WALCOTT.
Iron ores of the United States, HUNT, T. S.
Lower and middle Taconic, MARCOU.
Silurian system of rocks, MURCHISON.
Sedgwick and Murchison: Cambrian and Silurian, DANA.
Area of continental progress in North America, DANA.
Hercynian question, CLARKE, J. M, WALCOTT.
Quebec group of Logan, DAWSON, J. W.

[**SMITH**, Eugene A. and **GESNER**, William], Alabama.
Macfarlane's Geol. Railway Guide, 2d edition, pp. 378–382.
Geological notes for railway stations.

[**SMITH**, W. H.] [Notes on Hunter Island and Seine River sheet.]
Canada, Geol. Survey, Reports, vol. 3, new series, part 1 [Report A, pp. 76–77. 1888.
Brief reference to distribution of the crystalline rocks.

Smithsonian Institution, Annual Report, 1886, part 2.
Building stones in the National Museum, MERRILL.
———, 1888 (part 1).
Geology for 1887 and 1888, McGEE.
Paleontology of 1887 and 1888, WILLIAMS, H. S.
Petrography for 1887 and 1888, MERRILL, G. P.

SMOCK, John C. Iron mines and iron ore districts in the State of New York.
N. Y. State Museum, Bull., No, 7, 70 pages, map. 1889.
With incidental references to geologic relations.

——, New Jersey.
Macfarlane's Geol. Railway Guide, 2d edition, pp. 139–149.
Tables of formations of the State and geological notes for railway stations.

South America. Fernando de Noronha, BRANNER.
Ore deposits of Minas Geraes, Brazil, MEZGER.
Sergipe-Alagoas basin, Brazil, BRANNER.

Digitized by Google

South Carolina. Appomattox formation, McGEE.

Extent of Pleistocene submergence, McGEE.

Macfarlane's Railway Guide, HAMMOND.

Warren's Geography, BREWER.

SPENCER, J. W. The Iroquois beach; a chapter in the geological history of Lake Ontario.

Canada, Roy. Soc., Trans., vol. 7, Sec. IV, pp. 121–134.

Abstracts, Science, Jan, 1888; Am. Naturalist, vol. 24, p. 957, ½ p.; Am. Geologist, vol. 6, pp. 311–312.

Description of the beach and discussion of the glacial and post-glacial history of the region.

—— The deformation of Iroquois beach and birth of Lake Ontario.

Am. Jour. Sci., 3d series, vol. 40, pp. 443–451.

More in regard to the Iroquois beach and the history of the Lake Ontario basin.

—— The high continental elevation preceding the Pleistocene period.

Geol. Soc. Am., Bull., vol. 1, pp. 65–70.

Geological Magazine, 3d decade, vol. 7, pp. 208–213.

Abstract, Am. Naturalist, vol. 24, pp. 957–958, ½ p.

Discussion of the evidence in various regions.

—— Ancient shores, bowlder fragments, and high level gravel deposits in the region of the Great Lakes.

Geol. Soc. Am., Bull., vol. 1, pp. 71–86.

Description of the phenomena and discussion of their history and bearing.

—— [Remarks on rounded rock surfaces due to causes other than glacial erosion.]

Geol. Soc. Am., Bull., vol. 1, p. 175, ⅛ p.

Instances Stone Mountain in Georgia.

—— [Remarks on evidence of a general Pleistocene submergence.]

Geol. Soc. Am., Bull., vol. 1, p. 409, ½ p.

Brief references to occurrence and history of certain bowlder deposits in northwestern Canada, to the bearing of the old beaches of the Great Lakes and the Northwest, and to the occurrence of Pleistocene deposits at high altitude in Alabama.

—— [Remarks on the distribution and differentiation of certain gravel deposits in Ontario.]

Geol. Soc. Am., Bull., vol. 1, p. 546, ⅛ p.

Discussion of paper by G. F. Wright "A moraine of recession in Ontario."

SPENCER, J. W.—Continued.

—— Department of geology. "Southern Drift" and its agricultural relations. Bull. Exp. Sta., Ga., 1890, pp. 5. [Nothing further is known of the status of this pamphlet.]

A brief description of the characteristics and relations of the Tuscaloosa, Appomattox, and Columbia formations in the central Georgia region.

—— Origin of the basins of the Great Lakes of America.

Geol. Soc. Quart. Jour., vol. 46, pp. 523–531, 533.

Abstracts, Geol. Magazine, 3d decade, vol. 7, pp. 281–282, ⅛ p.; Am. Naturalist, vol. 25, p. 276, ½ p. 1891.

A general discussion of their origin and history.

—— The northeastern extension of the Iroquois beach of New York.

Am. Geologist, vol. 6, pp. 294–295, ¼ p.

Abstract, Popular Science Monthly, vol. 37, p. 718, ½ col.

Elevations. Warpings. Topography.

STEVENSON, J. J. [Remarks on shear in earth's crust movements and to the fractured condition of Pocono strata in Bedford County, Pennsylvania.]

Geol. Soc., Am., Bull., vol. 1, p. 26, ⅛ p.

In discussion of paper by G. K. Gilbert "The strength of the earth's crust."

—— [Remarks on the differentiation of the Colorado group in Colorado and New Mexico.]

Geol. Soc. Am., Bull., vol. 1, p. 532, ⅛ p.

Am. Naturalist, vol. 24, pp. 568–569.

Discussion of paper by J. S. Newberry, "The Laramie group."

STONE, George H. Classification of the glacial sediments of Maine.

Am. Jour. Sci., 3d series, vol. 40, pp. 122–144.

Abstract, Am. Geologist, vol. 7, pp. 136–137. 1891.

Includes discussions of their relations and history and conditions of deposition.

STORMS, W. H. The mines of Calico district, California.

Engineering and Mining Jour., vol. 49, pp. 382–383, 4°.

Description of geologic features.

—— Arizona's new bonanza.

Engineering and Mining Jour., vol. 50, pp. 162–163, 4°.

Includes brief statements in regard to geology and a cross-section of mine at Hillside, Yavapai County.

Digitized by Google

STREERUWITZ, W. von. Geology of Trans-Pecos, Texas. Preliminary statement.

Texas Geol. Survey, First Annual Report, pp. 217-233.

STREERUWITZ, W. von.—Continued.

Topography; Carboniferous, Cretaceous, and Pleistocene formations; metamorphics, eruptives, and economics.

T.

TARR, Ralph S. A preliminary report on the coal fields of the Colorado River.

Texas Geol. Survey, First Annual Report, pp. 199-216.

Carboniferous stratigraphy, relations to associated formations and coals.

— Drainage systems of New Mexico.

Am. Geologist, vol. 5, pp. 261-270.

General description of their relations and discussion of the history of their development.

— The Carboniferous area of central Texas.

Am. Geologist, vol. 6, pp. 145-153.

Extent, stratigraphy, subdivisions, thickness, structure, history, relations to Silurian, and erosion of the Cretaceous.

— Origin of some topographic features of central Texas.

Am. Jour. Sci., 3d series, vol. 39, pp. 306-311.

Discussion of the topographic development of the region with a prefatory account of the geologic history of the formations.

— On the lower Carboniferous limestone series in central Texas.

Am. Jour. Sci., 3d series, vol. 39, p. 404, ½ p.

Brief account of Carboniferous stratigraphy and relations of Silurian formations in central Texas.

— Superposition of the drainage in central Texas.

Am. Jour. Sci., 3d series, vol. 40, pp. 359-362.

Discussion of the relations and history of the Colorado and Brazos River systems.

— Erosive agents in the arid regions.

Am. Naturalist, vol. 24, pp. 455-459.

Brief review of the various inorganic and organic agencies.

Technology Quarterly, vol. 3, Nos. 1-3.

Kaolin in Blandford, Massachusetts, CROSBY.

Tennessee, Appomattox formation, MCGEE.

Calciferous formation, WALCOTT.

Tennessee—Continued.

Central basin, KENNEDY.

Macfarlane's Railway Guide, SAFFORD.

Warren's Geography, BREWER.

Tertiary. *Atlantic coast plain* (Massachusetts to South Carolina).

Cretaceous plants, Martha's Vineyard, WHITE, D.

Cretaceous fossils, Martha's Vineyard, SHALER.

Deposits of eastern Massachusetts, SHALER.

Gay Head, Massachusetts, CLARK. MERRILL, F. J. H.

Analyses of clay and sands from Gay Head, CLARKE, F. W. RIGGS.

Ancient shore lines, MERRILL, F. J. H.

Fiords and great lake basins of North America, UPHAM.

Long Island Sound and submerged channel of the Hudson, DANA.

Development of northern New Jersey, DAVIS and WOOD.

Artesian wells, Atlantic City, WOOLMAN.

Report—Division of Cenozoic invertebrates, U. S. Geol. Survey, DALL.

Artesian wells, New Jersey, NASON.

Traps of New Jersey region, DARTON.

Warren's Geography, BREWER.

Southern Maryland and Virginia, CLARK.

Potomac flora, FONTAINE.

Cape Fear River region, North Carolina, CLARK.

Distribution of fossil plants, WARD, L. F.

Southern extension of Appomattox formation, MCGEE.

Macfarlane's Railway Guide, CHANCE. CHESTER. CROSBY. FONTAINE. HAMMOND. HITCHCOCK. JOHNSON. ROGERS. SMOCK. UHLER.

Digitized by Google

Tertiary—Continued.

Gulf States (Florida to Texas), Phosphates of Florida, COX. GOLDSMITH. LEDOUX. WYATT.

Structure of oil-bearing strata.

Report—Division of Cenozoic invertebrates, U. S. Geol. Survey, DALL.

Observations on southern Florida, WILLCOX.

Tertiary fauna of Florida, DALL.

Topography of Florida, SHALER.

Orange sand formations, MCGEE.

Southern extension of Appomattox formation, MCGEE.

Peculiarities in drainage, MCGEE.

Mon Louis Island, Mobile Bay, LANGDON.

Southern drift of Georgia, SPENCER.

Saliferous deposits as evidence of climatal conditions, SHALER.

Report—Lower Mississippi division, U. S. Geol. Survey, JOHNSON, L. C.

Analysis of marble from Louisiana, HILLEBRAND.

Geographic features of Texas, HILL.

Permian of Texas, CUMMINS.

Pilot Knob, Texas, HILL.

Division of Mesozoic invertebrates, U. S. Geol. Survey, WHITE, C. A.

Central Texas, TARR.

Report on Gulf Tertiaries of Texas, PENROSE, R. A. F.

Review of Texas geology, DUMBLE.

Macfarlane's Railway Guide, SMITH and GESNER. HILGARD. JOHNSON. MCCUTCHEN.

Warren's Geography, BREWER.

Arkansas to Kansas. Crowley's Ridge, Arkansas, CALL.

Eastern Kansas, CALL.

Lineage of Lake Agassiz, TODD.

Kansas salt mine, HAY.

Southwestern Kansas, HAY.

Macfarlane's Railway Guide, LOUGHRIDGE. OWEN. ST. JOHN.

British Columbia. Caribou district, BOWMAN.

Fossil plants, DAWSON, J. W.

Distribution of fossil plants, WARD, L. F.

Mineral wealth, DAWSON, G. M.

Notes on Cretaceous, DAWSON, G. M.

Tertiary—Continued.

Seaboard of British Columbia, BOWMAN.

Serpentines of Canada, GIROUX.

Southern interior British Columbia, DAWSON, G. M.

Yukon district, DAWSON, G. M.

Laramie and its associates, TYRRELL.

Macfarlane's Railway Guide, DAWSON, G. M.

Central and western United States. Report—Division of Paleobotany, U. S. Geol. Survey, MARSH.

Distribution of fossil plants, WARD, L. F.

Uinta formation, SCOTT.

Skull of ceratopsidæ, MARSH.

Report of Geologist of Wyoming, RICKETTS.

Eastern Colorado, CANNON.

Spanish Peaks region, Colorado, HILLS.

Huerfano beds, HILLS.

Structural features near Denver, Colorado, ELDRIDGE.

Movements of Rocky Mountains, EMMONS.

Report—Rocky Mountains division, U. S. Geol. Survey, EMMONS.

Custer County, Colorado, CHARLTON.

Stratigraphy in Denver basin, ELDRIDGE.

Northwestern Colorado, WHITE, C. A.

Laramie group, NEWBERRY. STEVENSON. WARD, L. F.

Displacements in Grand Cañon, WALCOTT.

Drainage systems of New Mexico, TARR.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, BAILEY, G. E. BROADHEAD. DAVIS. EMMONS. GILBERT. HAGUE. PROCTER. PUMPELLY. SAFFORD. SCOTT. TODD. WILLIS.

Analyses of eruptive rocks, New Mexico, EAKINS.

California and Oregon. Auriferous gravels of California, HAMMOND.

Geology of quicksilver deposits, BECKER.

Islands of South Barbara channel, YATES.

Lassen Peak district, DILLER.

Digitized by Google

Tertiary—Continued.
Report—Division of volcanic geology, U. S. Geol. Survey, DUTTON.
Paleontology of northwest coast, DALL.
Protozoötites, FRIEDRICH.
Macfarlane's Railway Guide, CONDON. COOPER. HASTINGS. TURNER.
San Diego County, California, GOODYEAR.
Santa Cruz Island, GOODYEAR.
Santa Clara County, California, WEBER.
San Nicolas Island, BOWER.
Warren's Geography, BREWER.
Mexico. CHANCE.
Geologic map, CASTILLO.
Central America. Nicaragua, CRAWFORD.
Macfarlane's Railway Guide [Niobrara], COPE.
South America. Brazil, Sergipe-Alagôas basin, BRANNER.

Texas. American Neocomian, MARCOU.
A review of Texas geology, DUMBLE.
Basalt from Pilot Knob, KEMP.
Building stone, MERRILL, G. P.
Carboniferous of central Texas, TARR.
Central coal field, CUMMINS.
Central mineral region, COMSTOCK.
[Chalk.] Report—Division of Petrography, U. S. Geol. Survey, DILLER.
Classification of topographic features, HILL.
Coal fields, WEITZEL.
Coal fields of Colorado River, TARR.
Concho country, CUMMINS and LERCH.
Cretaceous of northern Mexico, WHITE, C. A.
Description of Cretaceous rocks, HILL.
Drainage of central Texas, TARR.
Eagle Flats formation, HILL.
Fossils of the Trinity beds, HILL.
Geographic features of Texas, HILL.
Geology of Trans-Pecos region, STREERUWITZ.
Gulf Tertiaries from Red River to Rio Grande, PENROSE, R. A. F.
Igneous rocks of central Texas, HILL and DUMBLE.
Indian Territory and Red River, HILL.

Texas—Continued.
List of Cretaceous invertebrates, HILL.
Macfarlane's Railway Guide, LOUGHRIDGE.
Movements in Rocky Mountains, EMMONS.
Occurrence of Goniolina in Comanche series, HILL.
Permian, CUMMINS.
Pilot Knob, HILL.
Report—Division of Mesozoic Paleontology, WHITE, C. A.
Staked Plains, HILL.
Topographic features of central Texas, TARR.
Valley of upper Canadian, HILL.
Warren's Geography, BREWER.

Texas, Geological Survey. First Annual Report.
A review of Texas geology, DUMBLE.
Gulf Tertiaries, PENROSE.
Cretaceous of Texas, HILL.
Southern border of central coal field, CUMMINS.
Permian of Texas, CUMMINS.
Coal fields of Colorado River, TARR.
Trans-Pecos Texas, STREERUWITZ.
Central mineral region, COMSTOCK.

Texas, Geological Survey. Bulletin No. 4.
List of Cretaceous invertebrates of Texas, HILL.

THOMPSON, Gilbert. A hypothesis for the so-called encroachments of the sea upon the land.
Science, vol. 15, p. 333, ⅔ col. 4°.
Discusses evidence of a seaward motion of the middle Atlantic coastal plain region.

TIFFANY, A. S. Record of deep well at Dixon, Illinois.
Am. Geologist, vol. 5, p. 124, ½ p.
Statement of rocks penetrated by a 1750-foot well.

TODD, J. E. The terraces of the Missouri. [Abstract.]
Iowa Acad. Sci., Proc., 1887-1889, pp. 11-12
Altitudes, deposits, subterrane, age, and history.

—— The origin of the extramorainic till. [Abstract.]
Iowa Acad. Sci., Proc., 1887-1889, pp 12 14.
Discussion of evidence presented in the Missouri Valley.

Digitized by Google

TODD, J. E.—Continued.

—— The lineage of Lake Agassiz. [Abstract.]

Iowa Acad. Sci., Proc., 1887-1889, pp. 57-58.
Sketch of the history of the basin from Eocene to Quaternary times.

—— On the folding of Carboniferous strata in southwestern Iowa. [Abstract.]

Iowa Acad. Sci., Proc., 1887-1889, pp. 58-62.
Description of the flexures and of the strata involved.

—— Deep well at Le Mars, Iowa.

Am. Geologist, vol. 5, pp. 124-125, ½ p.
Nature of rocks from 900 to 1,400 feet.

—— Nebraska.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 293-296.
General sketch of geology of State and geological notes for railway stations.

[——] [Notes on glacial deposits of North and South Dakota.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 253, 254, 255, 256.
Geological notes for railway stations.

TORREY, Joseph, jr., BARBOUR, Erwin H., and. Microscopic structure of oolite, with analyses.

Am. Jour. Sci., 3d series, vol. 40, pp. 246-249.
From Iowa, and Chester County, Pennsylvania.

[TURNER, H. W.] [Notes on California.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 320, 324, 326, ½ p.
Reference to the age of the rocks at San Francisco, formations in hills of Santa Rosa and Miocene at Alum Rock Cañon.

TYRRELL, J. B. Notes to accompany a preliminary map of the Duck and Riding Mountain in northwestern Manitoba.

Canada, Geol Survey, Reports, vol. 3, new series, part 1, Report E, 16 pages, map. 1888.
Abstracts, Ibid., Report A, pp. 14-18; Am. Geologist, vol. 5, pp. 241-242, ½ p.; Am. Jour Sci., 3d series, vol. 38, p. 78, ½ p.
Pleistocene deposits, shoreline features, and history. Brief references to Devonian and Cretaceous subterrane.

—— [Observations in southwestern Manitoba.]

Canada, Geol. Survey, Reports, vol. 3, new series, part 1, Report A, pp. 72-75. 1888.
Includes brief reference to glacial deposits, Cretaceous outcrops, a gypsum deposit, and a bore well through the Cretaceous to the Devonian.

TYRRELL, J. B.—Continued.

—— The Cretaceous of Manitoba.

Am. Jour. Sci., 3d series, vol. 40, pp. 227-232.
Relations, distribution, equivalency, and stratigraphy.

—— Post-Tertiary deposits of Manitoba and the adjoining territories in northwestern Canada.

Geol. Soc. Am., Bull., vol. 1, pp. 395-406, 407, 440.
Abstracts, Am. Geologist, vol. 5, p. 119, ½ p.; Am. Naturalist, vol. 24, pp. 208-209, ½ p.; Am. Jour. Sci., 3d series, vol. 40, p. 88-90.
An account of the distribution, characteristics, and relations of the various glacial and aqueous deposits and discussion of their history. Discussed by J. E. Mills, T. C. Chamberlin, N. S. Shaler, W J McGee, and J. W. Spencer, pp. 407-409.

—— [Remarks on the Laramie group and its associates in Canada.]

Geol. Soc. Am., Bull., vol. 1, pp. 528-529, ½ p.
In discussion of paper by J. S. Newberry on "The Laramie group."

UHLER, P. R. Maryland.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 332-334.
Geological notes for railway stations.

U. S. Geological Survey, Eighth Annual Report, 1886-'87, by J. W. Powell.

Division of Archean geology, PUMPELLY.
Division of coast line geology, SHALER.
Lake Superior division, IRVING.
Division of glacial geology, CHAMBERLIN.
Rocky Mountain division of geology, EMMONS.
Montana division of geology, PEALE.
California division of geology, BECKER.
Division of volcanic geology, DUTTON.
Paleozoic division of invertebrate paleontology, WALCOTT.
Division of Mesozoic paleontology, WHITE, C. A.
Division of paleobotany, WARD.
Quaternary history of Mono Valley, California, RUSSELL.
Geology of Lassen Peak district, DILLER.

Digitized by Google

U. S. Geological Survey—Continued.
Trenton limestone petroleum and gas in Ohio and Indiana, ORTON.
Geographical distribution of fossil plants, WARD.
Geology of quicksilver deposits of Pacific slope, BECKER.
Geology of Mt. Desert Island, Maine, SHALER.
———, Ninth Annual Report, 1887–'88, by J. W. Powell.
Atlantic coast division, SHALER.
Archean geology, PUMPELLY.
Lake Superior division, VAN HISE.
Yellowstone Park division, HAGUE.
Division of petrography, DILLER.
California division, BECKER.
Potomac division of geology, MCGEE.
Lower Mississippi division, JOHNSON.
Montana division of geology, PEALE.
Division of vertebrate paleontology, MARSH.
Division of Paleozoic invertebrates, WALCOTT.
Division of Mesozoic invertebrates, WHITE, C. A.
Division of Cenozoic invertebrates, DALL.
Division of Paleobotany, WARD.
Geology of Cape Ann, Massachusetts, SHALER.
Formation of travertin and sinter by vegetation of Hot Springs, WEED.
Northwestern Colorado and adjacent parts, WHITE, C. A.

U. S. Geological Survey, Bulletin No. 55. Triassic sandstone from Maryland, analysis, CLARKE, F. W.
Limestone near Defiance, Ohio, analysis, WHITFIELD, J. E.
Rocks from Menominee River, analysis, RIGGS.
Rocks from Pigeon Point, analyses, HILLEBRAND. WHITFIELD, J. E. RIGGS.
Rocks from Montana, analyses, CHATARD.
Lava from Shasta County, California, analysis, RIGGS.
Volcanic rocks from California, analyses, CHATARD. HILLEBRAND.
Clays from Owen's Lake, California, analyses, CHATARD.
Clays, sand, etc., from Martha's Vineyard, CLARKE. RIGGS.

U. S. Geological Survey, Bulletin No. 56. Fossil wood of the Potomac formation, KNOWLTON.
———, No. 57.
Introduction, MCGEE.
Reconnaissance in southwestern Kansas, HAY.
———, No. 58.
Introduction, CHAMBERLIN.
Glacial boundary in western Pennsylvania to Illinois, WRIGHT.
———, No. 59.
Gabbros and associates in Delaware, CHESTER.
———, No. 60.
Natural soda, CHATARD.
Novaculites, Michigan, analysis, HILLEBRAND.
Brick clay, Minnesota, analysis, CHATARD.
Rocks from Montana, analyses, CHATARD and EAKINS.
Limestones from Montana, analyses, CATLETT.
Eruptives from Henry Mountain, analyses, RIGGS.
Rocks collected by Irving, analyses, HILLEBRAND, CHATARD.
Rocks from New Mexico, analyses, EAKINS.
Lavas from Lassen Peak, analyses, HILLEBRAND. RIGGS.
Basalt, Asia Minor, analysis, CHATARD.
Sandstones, Berea, Ohio, analyses, EAKINS.
White earth from Georgia, analysis, CATLETT.
Inclusion in diorite, New York, analysis, CHATARD.
White marble, Cockeysville, Maryland, analysis, WHITFIELD, J. E.
Dolomite, Westchester County, New York, analysis, HILLEBRAND.
Dolomite and clay, Alabama, analysis, HILLEBRAND.
Marble from Louisiana, analysis, HILLEBRAND.
Limestones from Ohio, analyses, CLARKE and RIGGS.
Trenton limestones from Ohio and Indiana, analyses. CLARKE, F. W. CATLETT.
Coquina and coral rock from Florida, analyses, CLARKE, F. W.

Digitized by Google

U. S. Geological Survey, Bulletin No. 56—Continued.

Coquina, coral and coral rocks, analyses, EAKINS.

———, **No. 62.**

Explanatory and historical note, IRVING.

Greenstone schists of Menominee and Marquette region of Michigan, WILLIAMS, G. H.

———, **No. 64.**

Rocks from Baltimore County, Maryland, analyses, WHITFIELD, J. E. CHATARD.

Serpentines, analyses, CATLETT.

Geyserite from New Zealand, analyses, WHITFIELD, J. E.

Sandstone from Buena Vista, Ohio, analysis, CLARKE, F. W.

Sandstone from Portsmouth, Ohio, analysis, CHATARD.

Limestone from Silverdale, Kansas, analysis, CATLETT.

Rock from Marion, Kentucky, analysis, EAKINS.

Rocks from Pigeon Point, Michigan, analyses, EAKINS.

Diabase, Michigan, analysis, CHATARD.

Rocks from Penokee-Gogebic, Wisconsin, analyses, EAKINS.

Eruptive, Hot Springs, Arkansas, analysis, EAKINS.

Recent lavas from Arizona, analyses, EAKINS.

Eruptive, from Montana, analysis. EAKINS.

Rocks from northern California, analyses, WHITFIELD, J. E. EAKINS.

Adobe soils, analyses, EAKINS.

Clays, analyses, CATLETT.

———, **No. 65.**

Stratigraphy of coal rocks of northern half of the Appalachian field, WHITE, I. C.

———, **No. 66.**

Volcanic rocks from Tewan mountains, New Mexico, IDDINGS.

———, **No. 67.**

Traps of Newark system in New Jersey region, DARTON.

U. S. Geological Survey, Monographs. Vol. 1. Lake Bonneville, GILBERT.

U. S. Geological Survey, Monographs. Vol. 15. Potomac or younger Mesozoic flora, FONTAINE.

Vol. 16. Fossil fishes of the Paleozoic. NEWBERRY.

U. S. National Museum, Proceedings, Vol. 12.

Serpentinous rocks, MERRILL, G. H.

UPHAM, Warren. The growth, culmination, and departure of the Quaternary ice sheets.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 450–455.

Abstract, Am. Geologist, vol. 5, p. 123, ½ p.

A general review of the history of the glacial period, especially of the climatic conditions and their relations to continental uplift.

—— [Remarks on the exceptional character of the climate of the glacial period.]

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 465–466.

Discussion of evidence of glaciation in pre-Pleistocene times in various parts of the world and the cause of the climatic changes.

—— Quaternary changes of level.

Geol. Magazine, decade III, vol. 7, pp. 492–497.

Discussion of history and consequences of Pleistocene changes of level of North America and Europe.

—— The fiords and great lake basins of North America considered as evidence of preglacial continental elevation and of depression during the glacial period.

Geol. Soc. Am., Bull., vol. 1, pp. 563–567

—— Artesian wells in North and South Dakota.

Am. Geologist, vol. 6, pp. 211–212.

Discussion of conditions controlling depth, distribution, amount, pressure, and composition of the artesian waters.

—— On the cause of the glacial period.

Am. Geologist, vol. 6, pp. 327–339.

Abstract, Am. Naturalist, vol. 25, p. 277, ½ p. 1891.

Discusses evidence of a general great postglacial continental subsidence.

—— Pleistocene submergence of the Isthmus of Panama.

Am. Geologist, vol. 6, p. 396, ½ p.

Discussion of the bearing of certain fossiliferous deposits and the effect of the submergence on climatic conditions of the Ice age.

[——] [Notes on glacial features, Massachusetts and Minnesota.]

Digitized by Google

UPHAM, Warren—Continued.
Macfarlane's Geol. Railway Guide, 2d edition, pp. 107, 246–252.
Notes for railway stations.

[——] St. Paul, Minneapolis and Manitoba Railway.
Macfarlane's Geol. Railway Guide, 2d edition, p. 264.
Geological notes for the stations in Montana.

Utah, Analysis of adobe soil, EAKINS.
Analyses of rocks from Henry Mountains, RIGGS.
Lake Bonneville, GILBERT.
Origin of normal faults, READE.
Macfarlane's Railway Guide, DAVIS. GILBERT. HAGUE.
Movements in Rocky Mountains, EMMONS.
Northwestern Colorado region, WHITE, C. A.
Rocky Mountain protaxis, DANA.
Strength of the earth's crust, GILBERT.
Uinta formation, SCOTT.
Warren's Geography, BREWER.

V.

VAN DIEST, P. H. Remarks on the plication of the Coal Measures in southeastern Colorado and northeastern New Mexico.
Colorado Sci. Soc., Proc., vol. 3, pp. 185–190.
An account of the flexures and of the coal beds involved.

VAN HISE, C. R. The pre-Cambrian rocks of the Black Hills.
Geol. Soc. Am., Bull., vol. 1, pp. 203–244, pls. 4, 5.
Abstract, Am. Naturalist, vol. 24, pp. 291, 954, 1070–1071.
Distribution; structure; lithologic characters and history of the various rocks; nature of the original sediments; origin and age of the granites, and correlation and comparison with pre-Cambrian of Lake Superior region and elsewhere. Includes some brief general remarks of the permanency of clastic characters in rocks.

— [Remarks on certain questions of quivalency and structure of the crystallines of the Northwest.]
Geol. Soc. Am., Bull., vol. 1, pp. 390–391, 393.
Discussion of paper by A. Winchell on "Some results of Archean studies."

— Report—Lake Superior division.
U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 79–84. 1889.
Incidental reference to results of investigations by Irving and himself in the Penokee iron-bearing series, and by G. H. Williams in the Menominee-Marquette region.

Vassar College Institute, Transactions, vol. 5.

Trenton fossils at Pleasant Valley, New York, DWIGHT.

Cambrian system, DWIGHT.

Fossiliferous strata at Stissing, New York, DWIGHT.

Glacial phenomena, DWIGHT.

Vermont, Archean axes of eastern North America, DANA.
Calciferous in Champlain Valley, BRAINARD and SEELY. WALCOTT.
Bernardston series, EMERSON.
Building stone, MERRILL, G. P.
Granitoid areas in Lower Laurentian, HITCHCOCK.
Eolian limestones, HITCHCOCK.
Distribution of bowlders, HITCHCOCK.
Macfarlane's Railway Guide, HITCHCOCK.
Report, Paleozoic division of Paleontology, U. S. Geol. Survey, WALCOTT.
Rocks at Fort Cassin, WHITFIELD, R. P.
Taconic Mountains, AM. GEOLOGIST.
Warren's Geography, BREWER.

Virginia, Building stone, MERRILL, G. P.
Corundum in Patrick County, GENTH.
Dikes in Paleozoic series, DARTON. DILLER.
Evidence of glacial action in Virginia, MINOR.
Expedition into southern Maryland and Virginia, CLARK.
Fossil wood of Potomac formation, KNOWLTON.
Glacial climate [gravels], SHALER.
Macfarlane's Railway Guide, CAMPBELL. CHESTER. FONTAINE. ROGERS.
Notes on Richmond coal field, CLIFFORD.
Potomac flora, FONTAINE.
Triassic flora of Richmond, Virginia, MARCOU.
Warren's Geography, BREWER.

Google

W.

Wagner Free Institute of Science, Transactions, vol. 3.
Miocene fauna of Florida, DALL.

WALCOTT, C. D. Report—Paleozoic division of invertebrate paleontology.

U. S. Geol. Survey, 8th Report, J. W. Powell, pp. 174–178, 1889.

Includes brief reference to some results of explorations in Washington County and northern Dutchess County, New York, and in the roofing slates of Vermont.

—— Report—Division of Paleozoic invertebrates.

U. S. Geol. Survey, 9th Report, J. W. Powell, pp. 115–120, 1889.

Includes a brief account of results of investigations in the Taconic region of Washington County, and of the Hudson terrane in the Hudson valley and Schoharie County, New York.

—— A review of Dr. R. W. Ells's second report on the geology of a portion of the Province of Quebec; with additional notes on the "Quebec Group."

Am. Jour. Sci., 3d series, vol. 39, pp. 101–115.

Abstract, Am. Naturalist, vol. 24, p. 954, ½ p.

Abstracts from the report, comparison of statements of various observers concerning the region and discussion of stratigraphy and faunal relations of the lower Silurian and Cambrian.

—— Study of a line of displacement in the Grand Cañon of the Colorado in northern Arizona.

Geol. Soc. Am., Bull., vol. 1, pp. 49–64.

Abstract, Am. Naturalist, vol. 24, p. 110, 4 lines.

Description of the displacement phenomena and sketch of the various movements and their bearing on the geologic history of the region.

—— The value of the term "Hudson River Group" in geologic nomenclature.

Geol. Soc. Am., Bull., vol. 1, pp. 335–353, 354, 355.

Abstracts, Am. Geologist, vol. 5, p. 120, 6 lines.

Am. Naturalist, vol. 24, p. 955, 6 lines.

Review of the application and taxonomic value of the term, and of the distribution, characteristics, and general stratigraphic relations of the group. P. 355 announces the discovery of Niagara fossils in Washington

WALCOTT, C. D.—Continued.

County, New York. Discussed by James Hall and W. M. Davis, pp. 354–355.

—— [Remarks on the thickness and identity of the Calciferous formation from Canada to Tennessee.]

Geol. Soc. Am., Bull., vol. 1, pp. 512–513.

In discussion of paper by E. Brainerd and H. M. Seely on "The Calciferous formations in the Champlain valley."

[——] The Hercynian fauna of the northern Hartz in Germany.

Am. Jour. Sci., 3d series, vol. 39, pp. 155–156.

Description of paper of this title by J. M. Clarke, with a remark in regard to the classification of the Paleozoic groups.

WALDO, C. A. The petroleum belt of Terre Haute. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol 38, p. 250, ½ p.

Stratigraphic position, extent, and structure of oil-bearing strata.

WANNER, Atreus. Casts of scolithus flattened by pressure.

Am. Geologist, vol. 5, pp. 35–38.
York County, Pennsylvania.

—— The discovery of fossil tracks, algæ, etc., in the Triassic of York County, Pennsylvania.

Pennsylvania, Geol. Survey, Report for 1887, pp. 21–35.

With incidental descriptions of the containing beds.

WARD, Lester F. Report—Division of paleobotany.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 184–188, 1889.

Include brief reference to paleontologic evidence as to age of sandy clays at Grove Point on Chesapeake Bay, Maryland.

—— The geographical distribution of fossil plants.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 663–960, pl. LXI, 1889.

Consists of an enumeration of localities all over the world, with references as far as practicable to the age of the containing formations.

Pages 818–931 and the map relate to the United States under which the geological horizon of plant bearing beds is in some cases briefly discussed.

Digitized by Google

WARD, Lester F.—Continued.

— Report—Division of paleobotany.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 128–131, 1889.

Includes brief notice of the results of a reconnaissance in southern Montana.

— [Remarks on the age of the Laramie group.]

Geol. Soc. Am., Bull., vol. 1, pp. 529–532.

Am. Naturalist, vol. 24, pp. 564–568.

Discussion of paper by J. S. Newberry on "The Laramie group."

— [Remarks on the Cretaceous formation in Gay Head.]

Geol. Soc. Am., Bull., vol. 1, pp. 555–556, ½ p.

Am. Naturalist, vol. 24, pp. 562–563.

Discussion of paper by D. White, on "Cretaceous plants from Martha's Vineyard."

WARD, T. On the salt deposits of the United States of America and Canada, with notes on a visit to the more important of them.

Manchester, Geol. Soc., Trans., vol. 20, pp. 471–496.

Includes some brief incidental geologic references, mainly from previous writers.

Warren's New Physical Geography, BREWER.

Washburn College Laboratory, Bulletin, vol. 11, No. 2.

Cheyenne sandstone and Neocomian of Kansas, CRAGIN.

Washington, Macfarlane's Railway Guide, DAWSON, G. M. WILLIS.

Washington Philosophical Society, Bulletin, vol. 11, pp. 191–220.

Igneous rocks in Yellowstone Park, IDDINGS.

WEBER, A. H. Santa Clara County.

California, Ninth Report of Mineralogist, pp. 48–56.

Includes references to geology.

WEBSTER, Clement L. The transitional drift of a portion of northern Iowa.

Am. Naturalist, vol. 24, pp. 1182–1185.

Description of a hitherto undifferentiated member of the drift formations, with remarks on its history.

WEED, Walter Harvey. Formation of travertine and siliceous sinter by the vegetation of hot springs.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 613–676, pls. 78–87.

Abstracts, Am. Jour. Sci., 3d series, vol. 41, pp. 158–159, 1891; Am. Geologist, vol. 7, p. 201, ½ p. 1891.

Description of the deposits and discussion of their origin and rate and condition of deposition. Relates mainly to the Yellowstone Park accumulations, but also includes a brief account of those of New Zealand.

—— Diatom beds and bogs of the Yellowstone National Park.

Botanical Gazette, vol. 14.

Abstract, Am. Jour. Sci., 3d series, vol. 39, p. 521, ½ p.

—— Geysers.

School of Mines Quart., vol. 11, pp. 289–306.

Review of geyser theories, prefaced by brief accounts of the geyser phenomena in various parts of the world.

WELLS, David A. Evidences of glacial action in southeastern Connecticut.

Popular Science Monthly, vol. 37, pp. 196–201.

Descriptions and illustrations of some notable bowlders and remarks on their history and the glacial history of the region.

WEITZEL, R. S. The coal fields of Texas.

Engineering and Mining Jour., vol. 50, pp. 214–216, 2 cols., 4°.

Includes references from various sources.

West Indies. Analysis of coral, EAKINS.

Notes on geology of the Bahamas, NORTHRUP.

Vincelonian volcano, SHARP.

West Virginia. Glacial boundary, CHAMBERLIN. WRIGHT.

Macfarlane's Railway Guide, PARSONS. WHITE, I. C.

Warren's Geography, BREWER.

WHITE, C. A. The North American Mesozoic.

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 205–226.

Abstract, Popular Science Monthly, vol. 37, pp. 140, 141, ½ col.

A general review.

—— Report—Division of Mesozoic paleontology.

U. S. Geol. Survey, Eighth Report, J. W. Powell, pp. 178–181, 1889.

Includes an account of studies of the Cretaceous formations in Texas.

—— Report—Division of Mesozoic invertebrates.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 120–123, 1889.

Digitized by Google

WHITE, C. A.—Continued.

Includes statements regarding the classification of the Texas Cretaceous formations and the relations of the Laramie group on the Rio Grande.

—— On the geology and physiography of a portion of northeastern Colorado and adjacent points of Utah and Wyoming.

U. S. Geol. Survey, Ninth Report, J. W. Powell, pp. 677–712, Pl. LXXVIII, 1889.

Abstract, Am. Geologist, vol. 7, pp. 57–58, 1891.

Description of the Archean, Uinta, Carboniferous, Cretaceous, and Tertiary formations, and the structural features, and review of the relations and the history of the displacements. With a colored geologic map

—— Remarks on the Cretaceous of northern Mexico. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, p. 252.

State of Chihuahua and adjacent parts of Texas and New Mexico. Thickness, equivalency of stratigraphic components, and relations of underlying Carboniferous.

—— The lower Cretaceous of the San Carlos Mountains, New Mexico.

Am. Jour. Sci., 3d series, vol. 39, p. 70, ½ p.

Statement of opinion in regard to its history.

WHITE, David. On Cretaceous plants from Martha's Vineyard.

Am. Jour. Sci., 3d series, vol. 39, pp. 93–101, Pl. II.

Abstracts, Geol. Soc. Am., Bull., vol. 1, pp. 554-555; Am. Geologist, vol. 5, p. 121, ½ p.

List of plants, review of previous observers, and discussion of the horizon of the plant-bearing series.

Discussed by J. S. Newberry, L. F. Ward, F. J. H. Merrill, Geo. Soc. Am., Bull., vol. 1, pp. 553–556.

WHITE, I. C. [Remarks on the history of the glacial deposits in the upper Ohio region.]

Geol. Soc. Am., Bull., vol. 1, pp. 477–478, 479–480.

In discussion of paper by T. C. Chamberlin on "Some additional evidence bearing on the interval between the glacial epochs."

—— [Remarks on pressure of gas in western Pennsylvania region.

Geol. Soc. Am., Bull., vol. 1, pp. 95–96.

In discussion of memoir by Edward Orton on "Origin of rock pressure of natural gas."

[——] Pittsburg and Lake Erie Railroad.

Macfarlane's Geol. Railway Guide, 2d edition, p. 174, ½ p.

Geological notes for the stations.

[——] West Virginia [and Chesapeake and Ohio Railroad in Kentucky].

WHITE, I. C.—Continued.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 337–351.

Description of the formations of West Virginia and geological notes for railway stations.

WHITEAVES, J. F. Description of eight new species of fossils from the Cambro-Silurian rocks of Manitoba.

Canada, Roy. Soc., Trans., vol. 7, section iv, pp. 75–83, Pls. XII–XVII..

Abstract, Am. Geologist, vol. 5, p. 58, ½ p.

Includes (½ page) note on the equivalency of the Cambro-Silurian members in Manitoba.

WHITFIELD, J. Edward. Limestone from the Auglaize River near Defiance, Ohio. [Partial analysis.]

U. S. Geol. Survey, Bull., 55, p. 80, ½ p., 1889.

—— Rocks from Pigeon Point, Minnesota. [Analysis.]

U. S. Geol. Survey, Bull., No. 55, pp. 81–82, 1889.

—— White dolomite marble, Cockeysville, Maryland. [Analysis.]

U. S. Geol. Survey, Bull. No. 60, p. 159, ½ p.

—— Rocks from Baltimore County, Maryland. [Analysis.]

U. S. Geol. Survey, Bull. No. 64, p. 42, ½ p.

Pyroxenites.

—— Geyserites from Rotorua, New Zealand. [Analyses.]

U. S. Geol. Survey, Bull. No. 64, p. 45, ½ p.

—— Eruptive rocks from northern California. [Analyses.]

U. S. Geol. Survey, Bull. No. 64, pp. 49–50.

WHITFIELD, R. P. Observations on the fauna of the rocks at Fort Cassin, Vermont, with descriptions of a few new species.

Am. Museum Nat. Hist., Bull., vol. 3, pp. 25–39, pls. 1–3.

With prefatory discussion of the stratigraphic position of the members in the Fort Cassin region.

—— The Fort Cassin rocks and their fauna.

Geol. Soc., Am., Bull., vol. 1, pp. 514–515.

Discussion of faunal evidence as to their age and equivalency.

WILLCOX, Joseph. [Observations on geology of southern Florida.]

U. S. Geol. Survey, Ninth Report, J. W. Powell, p. 126, ½ p. 1889.

Noted by W. M. Dall, Report—division of Cenozoic invertebrates.

Digitized by Google

WILLIAMS, George Huntington. The greenstone schist areas of the Menominee and Marquette regions of Michigan; a contribution to the subject of dynamic metamorphism in eruptive rocks.

U. S. Geol. Survey, Bull. No. 62, pp. 31-241, pls. III-XVI.

Petrographic descriptions and discussion of the origin of the rocks and the history of their metamorphism. Includes incidental descriptions of relations in the field, and a chapter on the present state of knowledge regarding the metamorphism of eruptive rocks. Illustrated by colored micro-petrographic plates.

—— The nonfeldspathic intrusive rocks of Maryland, and the course of their alteration.

Am. Geologist, vol. 6, pp. 35-49.

Mainly petrographic. Includes an account of their occurrence and geologic relations.

—— Note on the eruptive origin of the Syracuse serpentine.

Geol. Soc. Am., Bull., vol. 1, pp. 533-534.

Abstracts, Am. Geologist, vol. 5, p. 118, ½ p. Am. Naturalist, vol. 24, p. 211, 4 lines.

Description of new exposures exhibiting the relations of the dike and the occurrence of inclusions. Remarks by James Hall and J. F. Kemp, p. 534, ½ p.

—— Geological and petrographical observations in southern and western Norway.

Geol. Soc. Am., Bull., vol. 1, pp. 551-553.

Abstracts, Am. Geologist, vol. 5, pp. 120-121, ½ p.; Am. Naturalist, vol. 24, pp. 210-211, ½ p.

Mainly in regard to metamorphism: discussed by B. K. Emerson, p. 553, ½ p.

—— Significance of oval granitoid areas.

Geol. Soc. Am., Bull., vol. 1, p. 558, ½ p.

Discussion of paper by C. H. Hitchcock on "Significance of oval granitoid areas in the lower Laurentian."

—— On a geological excursion in the northern Appalachian chain.

Johns Hopkins Univ., Circulars, vol. 10, No. 84, pp. 27-28, 1½ cols., 4°.

Remarks on observations on the crystalline rocks of western New England, the crystalline limestones of New Jersey, the structure and relations of eruptives and metamorphics constituting the Adirondacks in New York, and the Huoting series of Canada.

—— [Notice of the results of studies in the Menominee and Marquette regions.]

U. S. Geol. Survey, Eigth Report, J. W. Powell, p. 135, ½ p. 1889.

WILLIAMS, George H.—Continued.

Brief reference to nature and origin of certain rocks.

—— [Notice of results of petrographic studies in the greenstone schist areas of the Marquette and Menominee regions of Michigan.]

U. S. Geol, Survey, Ninth Report, J. W. Powell, p. 83, ½ p. 1889.

Stated by C. R. Van Hise in Report—Lake Superior division.

—— Geology of the vicinity of Baltimore.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 334-335.

Description of the crystalline rocks.

WILLIAMS, H. S. The Devonian system of North and South Devonshire.

Am. Jour. Sci., 3d series, vol. 39, pp. 31-38.

Abstract, Am. Assoc. Adv. Science, Proc., vol. 38, pp. 233-234, ½ p.

Geologic and faunal characteristics and comparison of faunæ with those of the North American formations.

—— The Cuboides zone and its fauna; a discussion of methods of correlation.

Geol. Soc. Am., Bull., vol. 1, pp. 481-500, pls. 11-13.

Abstracts, Am. Geologist, vol. 5, p. 120, ½ p. Am. Naturalist, vol. 24, pp. 290, 706, ½ p.

Comprises a discussion of principles of correlation and the homotaxis of the Tully limestone of New York and the Cuboides zone of Europe.

—— North American paleontology for 1887 and 1888.

Smithsonian Institution, Report, 1888 (part 1), pp. 261-326.

Contains incidental references to the geologic bearing of some of the paleontologic papers.

[——] The American committee of the International Congress of Geologists.

Am. Jour. Sci., 3d series, vol. 40, pp. 166-167.

Discussion of its status.

[——] [Geological notes in central and western New York.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 121, 123, 131.

Delaware, Lackawana and Western Railway from Binghamton to Buffalo and West Shore Railway from Albany to Buffalo.

[**WILLIS**, Bailey.] Washington.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 264-266.

Geological notes for railroad stations.

WILLISTON, S. W. Chalk from the Niobrara Cretaceous of Kansas.

Digitized by Google

WILLISTON, S. W.—Continued.

Science, vol. 16, p. 294, ⅓ col., 4°.

An account of the organic components.

WINCHELL, Alexander. Some results of Archean studies.

Geol. Soc. Am., Bull., vol. 1, pp. 357–390, 392–393.

Abstracts, Am. Geologist, vol. 5, p. 121, ½ p. Am. Naturalist, vol. 24, pp. 291–292.

A discussion of the relations, structure, classification, age, and history of the crystalline rocks of the Northwest, especially in the northeastern Minnesota region.

Discussed by C. R. Van Hise, pp. 391–393.

—— [Strength of the earth's crust.]

Geol. Soc. Am., Bull., vol. 1, pp. 25–26, ½ p.

Discussion of paper by G. K. Gilbert with that title.

—— [Remarks on the distribution of bowlders in the lower peninsula of Michigan.]

Geol. Soc. Am., Bull., vol. 1, p. 29, ½ p.

In discussion of paper by T. C. Chamberlin on "Bowlder belts distinguished from bowlder trains."

—— The geological position of the Ogishke conglomerate. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 234–235, ½ p.

—— Recent observations on some Canadian rocks.

Am. Geologist, vol. 6, pp. 360–370.

Between Sault Ste. Marie and Echo River, on the river Ste. Marie and in the vicinity of Echo Lake. Description of Huronian rocks and their ferruginous deposits, and discussion of the relation and equivalency of the rocks of the Echo Lake region.

—— Michigan.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 189–197.

Sketch of the geology of Michigan, list of formations and geologic notes for railway stations.

—— Recent views about glaciers.

The Forum, vol. 10, pp. 306–314.

A general review of glacial theories.

[**WINCHELL**, N. H.] Northern Pacific Railroad.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 258–259.

Geologic notes for stations in Minnesota and eastern Dakota.

—— and **WINCHELL**, H. V. On a possible chemical origin of the iron ores of the Keewatin in Minnesota.

Am. Assoc. Adv. Sci., Proc., vol. 38, pp. 235–242.

WINCHELL, N. H., and **WINCHELL**, H. V.—Continued.

The Taconic iron ores of Minnesota and western New England.

Am. Geologist, vol. 6, pp. 263–274.

Abstract, Am. Jour. Sci., 3d series, vol. 40, p. 332, ½ p.

Discussion of the equivalency of certain ore horizons in the two regions and a review of the age and relations of the limestones of western New England.

WINSLOW, Arthur. Notes on the coal beds of Lafayette County.

Missouri, Geol. Survey, Bull. No. 1, pp. 14–21.

Extent, thickness, age, geologic map.

Wisconsin, Analyses of rocks collected by Irving, HILLEBRAND.

Analyses of rocks from Menominee River, RIGGS.

Analyses of rocks from Penokee-Gogebic range, EAKINS.

A recent rock-flexure, CRAMER.

Glacial sand plains, DAVIS.

Greenstone schists of Menominee-Marquette region, WILLIAMS, G. H. IRVING.

Pre-Cambrian of the Black Hills of Dakota, VAN HISE.

Report—Lake Superior division, U. S. Geol. Survey, IRVING. VAN HISE.

Warren's Geography, BREWER.

Macfarlane's Railway Guide, CHAMBERLIN.

WITTER, F. M. Some additional observations on the loess in and about Muscatine. [Abstract.]

Iowa Acad. Sci., Proc., 1887–1889, p. 45, ½ p.

Description of its characteristics and reference to its organic remains.

WOOD, Herbert R. Kamanistiquia silver-bearing belt.

Canadian Inst., Proc., vol. 7, pp. 245–259.

With brief prefatory notes on its geology.

WOOD, J. Walter, jr., **DAVIS**, William Morris, and. The geographic development of northern New Jersey.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 365–423.

Abstract, Am. Geologist, vol. 6, pp. 195–196, ½ p.

An analysis of the history recorded in the topography and drainage of the region.

WOLFF, J. E. On some occurrences of ottrelite and ilmenite schist in New England.

Digitized by Google

WOLFF, J. E.—Continued.

Harvard Col., Mus. Comp. Zoöl., Bull., vol. 16, pp. 159–165.

Petrographic descriptions of specimens from Rhode Island and western Massachusetts.

—— The geology of the Crazy Mountains, Montana.

Am. Naturalist, vol. 24, p. 290, 6 lines.

Notice of paper read to Geol. Society of America, December, 1889. Reference to relations of eruptives to the Cretaceous strata.

WOODWARD, R. S. See **GILBERT, G. K., Lake Bonneville.**

WOOLMAN, Lewis. Geology of artesian wells at Atlantic City, New Jersey.

Philadelphia, Acad. Nat. Sciences, Proc., 1890, pp. 132–147, plate.

Abstract by author, N. J. Geol. Survey, Report for 1889, pp. 89–99, plate.

Abstract, Popular Science Monthly, vol. 37, pp. 848–849, 7 lines.

Descriptions and columnar record of the borings, list of fossils and remarks on the horizon and the equivalency of the formations penetrated.

—— Marine and fresh water diatoms and sponge-spicules from the Delaware River clays of Philadelphia.

Philadelphia, Acad. Nat. Sciences, Proc., 1890, pp. 189–191.

With incidental references to exposures and the history of the beds.

WOOSTER, L. C. The permo-Carboniferous of Greenwood and Butler Counties, Kansas.

Am. Geologist, vol. 6, pp. 9–18.

Stratigraphy. Equivalency. Fauna. Drainage and superficial deposits.

[WORTHEN, A. H.] Illinois.

Macfarlane's Geol. Railway Guide, 2d edition, pp. 209–221.

Geologic notes for railway stations.

WRIGHT, George Frederick. The glacial boundary in western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois.

U. S. Geol. Survey, Bull., No. 58, pp. 39–110, pls. 1–7.

Abstract, Am. Geologist, vol. 6, pp. 390–391, ½ p.

Distribution of till near the margin from New England to Missouri. Striated rock surfaces. Hypothesis of a glacial dam at Cincinnati. The loess and its relations to the glacial drift. Interglacial man in Ohio.

WRIGHT, George F.—Continued.

—— The lake ridges of Ohio and their probable relations to the lines of glacial drainage into the valley of the Susquehanna. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 38, p. 247, ½ p.

Abstract, Popular Science Monthly, vol. 36, pp. 423–424, ½ col.

—— [Remarks on disposition of bowlders in the morainal fringes.]

Geol. Soc. Am., Bull., vol. 1, pp. 29–30.

In discussion of paper by T. C. Chamberlin on "Bowlder belts distinguished from bowlder trains."

—— A moraine of recession in Ontario.

Geol. Soc. Am., Bull., vol. 1, pp. 544–545.

Abstract, Am. Naturalist, vol. 24, p. 209, ½ p.; p. 771, 4 lines.

Topography, structure, and history.

Discussed by J. W. Spencer, p. 546, ½ p.

[——] [Notes on glacial features.]

Macfarlane's Geol. Railway Guide, 2d edition, pp. 178, 179, 181, 182, 184, 185, 206, 221, 395, ½ p.

For certain districts in Ohio, Indiana, Illinois, and Kentucky.

WYATT, Francis. Notes on Florida phosphate beds.

Engineering and Mining Jour., vol. 50, pp. 218–220. 4°.

Geologic relations, history, and composition, mainly of deposits in Marion and Citrus counties.

Wyoming, Diatom beds, Yellowstone Park, WEED.

Geysers, WEED.

Macfarlane's Railway Guide, HAGUE. SCOTT.

Laramie group, NEWBERRY. WARD, L. F.

Northwestern Colorado region, WHITE, C. A.

Report—Yellowstone Park division, U. S. Geol. Survey, HAGUE.

Report of geologist, RICKETTS.

Skull of Ceratopsidæ, MARSH.

Traventine and siliceous sinter, WEED.

Uinta formation, SCOTT.

Warren's Geography, BREWER.

Wyoming, Annual Report of the Territorial Geologist, RICKETTS.

Digitized by Google

Y.

YATES, Lorenzo Gordin. Notes on the geology and scenery of the islands forming the southern line of the Santa Barbara Channel.
Am. Geologist, vol. 5, pp. 43–52.
Relations, distributions, and topography of volcanic materials and Tertiary sediments.

—— Stray notes on the geology of the Channel Islands.
California, Ninth Report of Mineralogist, pp. 171–174, map.

O

Digitized by Google

DEPARTMENT OF THE INTERIOR

[illegible] 1892

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 92

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE COMPRESSIBILITY OF LIQUIDS

BY

CARL BARUS

WASHINGTON

GOVERNMENT PRINTING OFFICE

1892

Digitized by Google

Digitized by Google

CONTENTS.

	Page
Letter of transmittal	13
Preface	15
Chapter I. Fluid volume: Its dependence on pressure and temperature	17
Introduction	17
Literature of compressibility	17
Literature of heat expansion	19
Remarks on the literature	20
Apparatus	20
Force pump and appurtenances	20
Pressure tube and appurtenances	20
Method of charging the tube	21
Method of heating	22
Pressure measurement	23
Volume changes of the glass tubes	25
Mercury tests	25
Isothermals and adiabatics	26
Thermal expansion	27
Experimental results	28
Explanation	28
Ether	28
Alcohol	30
Palmitic acid	32
Para-toluidine	33
Diphenylamine	34
Caprinic acid	35
Benzoic acid	35
Paraffin	36
Thymol	37
Naphthalene	40
Method of discussion	42
Plan pursued	42
Quadratic constants	42
Compressibility increasing inversely as the pressure binomial	43
Transition to exponential constants	43
Properties of the exponential equation	44
Exponential constants computed	46
Mean exponential constants derived	48
Subsidiary results	49
Isothermals computed	50
Isometrics	54
Digression on thermal expansion	55
Exponential equation proposed	55
Observed contractions due to cooling under pressure	56

Digitized by Google

Page.

Chapter I. Fluid volume: Its dependence on pressure and temperature—Continued.
Compressibility increasing inversely as the second power of the pressure binominal 61
Properties of the hyperbolic equation 61
Presumptive character of the isometrics 62
Hyperbolic constants computed 63
Mean hyperbolic constants derived 64
The isothermal band 65
Conclusion 65
Chapter II. The effect of pressure on the electrical conductivity of mercury. 68
Introductory 68
Purposes of the work 68
Literature 69
Simple methods and results 69
Cailletet's tubes described 69
Electrical apparatus 70
Preliminary data 70
Correction for volume changes of tube 71
Preliminary result stated 71
Piezometer methods and results 72
Tubular piezometer described 72
Results 73
Deductions 74
Purely thermal variation of resistance 74
Comparison with J. J. Thomson's equation 75
Zero of resistance 75
Electrical pressure measurement 75
Measurement of melting point and pressure 76
Conclusion 76
Chapter III. The compressibility of water above 100° and its solvent action on glass 78
Introduction 78
Behavior of water 78
Literature. Compressibility of water 78
Literature. Solvent action of water 79
Method of measurement and results 79
Apparatus 79
Low temperature data 80
High temperature data 80
Discussion of these results 81
High temperature measurement repeated 82
Discussion of these results 82
Conclusion 83
Chapter IV. The solution of vulcanized india rubber 85
The present application 85
Solution in carbon disulphide 86
Solution in liquids of the paraffin series 87
Solution in turpentine 87
Solution in chloroform and carbon tetrachloride 87
Solution in aniline 88
Solution in animal oils 88
Treatment with glycerin 88
Solution in benzol and higher aromatic hydrocarbons 88

Digitized by Google

Page.

Chapter IV. The solution of vulcanized india rubber—Continued.
Solutions in ethylic and higher ethers 88
Treatment with alcohols 88
Treatment with ketones 88
Treatment with water and mineral acids 88
Treatment for vulcanization. Liquid ebonite 89
Solution in mixtures of solvents, and solution of mixed gums 89
Direct devulcanization 90
Fusion of impregnated rubber 90
Behavior of reagents and solvents 92
Summary of the results 93
Presumable conditions regarding the solution of carbon, etc 93
Index 95

Digitized by Google

Digitized by Google

TABLES.

		Page
Table 1.	Compressibility of air. Test of gauge	24
2.	Comparison of gauges	24
3.	Compressibility of mercury. Test of tubes	26
4.	Compressibility of ether	29
5.	Compressibility of ether, referred to 100 atmospheres	30
6.	Thermal expansion of ether, referred to 29°	30
7.	Compressibility of alcohol	31
8.	Compressibility of alcohol, referred to 150 atmospheres	31
9.	Thermal expansion of alcohol, referred to 28°	32
10.	Compressibility of palmitic acid	32
11.	Thermal expansion of palmitic acid, referred to 65°	33
12.	Compressibility of para-toluidine	33
13.	Thermal expansion of para-toluidine, referred to 28°	34
14.	Compressibility of diphenylamine	34
15.	Thermal expension of diphenylamine, referred to 66°	34
16.	Compressibility of caprinic acid	35
17.	Thermal expansion of caprinic acid, referred to 30°	35
18.	Compressibility of benzoic acid	35
19.	Compressibility of paraffin	36
20.	Thermal expansion of paraffin, referred to 64°	36
21.	Compressibility of paraffin	37
22.	Compressibility of thymol	37
23.	Thermal expansion of thymol, referred to 28°	38
24.	Compressibility of monobrom camphor	38
25.	Thermal expansion of monobrom camphor, referred to 100°	39
26.	Compressibility of α naphthol	39
27.	Thermal expansion of α naphthol, referred to 100°	39
28.	Compressibility of azobenzol	39
29.	Thermal expansion of azobenzol, referred to 100°	40
30.	Compressibility of vanilline	40
31.	Thermal expansion of vanilline referred to 100°	40
32.	Compressibility of naphthalene	41
33.	Compressibility of monochlor-acetic acid	41
34.	Quadratic constants which reproduce the isothermal decrements	43
35.	Exponential constants which reproduce the isothermal decrements. Direct computation	47
36.	Mean exponential constants	49
37.	Compressibility at melting and at boiling points	50
38.	Isothermals of ether, referred to unit of volume at2 8° and 100 atmospheres	51
39.	Isothermals of alcohol, referred to unit of volume at 28° and 150 atmospheres	51

Digitized by Google

Page.

Table 40. Isothermals of paraffin, referred to unit volume at 65° and 20 atmospheres 52
41. Isothermals of diphenylamine, referred to unit volume at 65° and 0 atmosphere 52
42. Isothermals of para-toluidine, referred to unit volume at 28° and 20 atmospheres 53
43. Isothermals of thymol, referred to unit volume at 28° and 20 atmospheres 53
44. Expansion and compression constants of ether 56
45. Contraction due to cooling under pressure. Paraffin 58
46. Contraction due to cooling under pressure. Paraffin 58
47. Contraction due to cooling under pressure. Paraffin 59
48. Contraction due to cooling under pressure. Paraffin 60
49. Contraction due to cooling under pressure. Naphthalene 60
50. Contraction due to cooling under pressure. Monochlor-acetic acid. 61
51. Hyperbolic constants which reproduce the isothermal decrements. Direct computation 64
52. Mean hyperbolic constants 64
53. Isothermals of ether. Direct measurement 66
54. Effect of compression on the resistance of mercury and of zinc sulphate solution 70
55. Effect of isothermal compression on the electric resistance of mercury. Piezometer method 73
56. Compressibility of water at low temperatures 80
57. Compressibility of water at higher temperatures 81
58. Compressibility of water 82
59. Contraction and compressibility of silicated water. Referred to water at 24° and 20 atmospheres 82

Digitized by Google

ILLUSTRATIONS.

Plate		Page.
	I.—Capillary tube, with appurtenances, for measuring the compressibility of liquids. Scale, one-third	20
	II.—Approximate compressibility of mercury	26
III.	Fig. 1. Relative isothermals of ether. $p_0=100$ atmospheres, $\theta_0=29°$	28
	Fig. 2. Relative isopiestics of ether. $p_0=100$ atmospheres, $\theta_0=29°$	28
IV.	Fig. 1. Relative isothermals of alcohol. $p_0=150$ atmospheres, $\theta_0=28°$	30
	Fig. 2. Relative isopiestics of alcohol. $p_0=150$ atmospheres, $\theta_0=28$	30
V.	Fig. 1. Relative isothermals of palmitic acid. $p_0=20$ atmospheres, $\theta_0=65°$	32
	Fig. 2. Relative isopiestics of palmitic acid. $p_0=20$ atmospheres, $\theta_0=65°$	32
VI.	Fig. 1. Relative isothmals of toluidine. $p_0=20$ atmospheres, $\theta_0=28°$	34
	Fig. 2. Relative isopiestics of toluidine. $p_0=20$ atmospheres, $\theta_0=28°$	34
VII.	Fig. 1. Relative isothermals of diphenylamine. $p_0=0$, $\theta_0=66°$.	36
	Fig. 2. Relative isopiestics of diphenylamine. $p_0=0$, $\theta_0=66°$..	36
VIII.	Fig. 1. Relative isothermals of caprinic acid. $p_0=20$ atmospheres, $\theta_0=30°$	38
	Fig. 2. Relative isopiestics of caprinic acid. $p_0=20$ atmospheres, $\theta_0=30°$	38
IX.	Fig. 1. Relative isothermals of paraffin. $p_0=20$ atmospheres, $\theta_0=65°$	40
	Fig. 2. Relative isopiestics of paraffin. $p_0=20$ atmospheres, $\theta_0=65°$	40
	X.—Relative isothermals of paraffin. $p_0=0$, $\theta_0=65°$	42
XI.	Fig. 1. Relative isothermals of thymol. $p_0=20$ atmospheres, $\theta_0=28°$	44
	Fig. 2. Relative isopiestics of thymol. $p_0=20$ atmospheres, $\theta_0=28°$	44
	XII.—Relation of pressure coefficient and compressibility	46
XIII.	Fig. 1. Isothermals of alcohol	48
	Fig. 2. Isometrics of alcohol	48
XIV.	Fig. 1. Isothermals of ether	50
	Fig. 2. Isopiestics of ether	50
XV.	Fig. 1. Isothermals of paraffin	52
	Fig. 2. Isometrics of paraffin	52
	XVI.—Isothermals of diphenylamine	54
	XVII.—Isothermals of toluidine	56
	XVIII.—Isothermals of thymol	58

Digitized by Google

Plate XIX.—Isometrics of ether, alcohol, paraffine, diphenylamine, toluidine, and thymol compared 60
XX.—Thermodynamic surface 62
XXI.—Contraction on cooling. Paraffin 64
XXII. Fig. 1. Contraction on cooling under pressure. Paraffin. 20 and 400 atmospheres 66
Fig. 2. Contraction on cooling under pressure. 20 and 500 atmospheres 66
Fig. 3. Contraction on cooling under pressure. 20 and 600 atmospheres 66
Fig. 4. Relative rates of contraction. Paraffin 66
XXIII.—Contraction on cooling under pressure. Paraffin 68
XXIV.—Contraction on cooling under pressure. Naphthalene 70
XXV. Fig. 1. Contraction on cooling under pressure. Monochloracetic acid 72
Fig. 2. Relative rates of contraction. Monochloracetic acid 72
XXVI.—Apparatus for compressing mercury 74
XXVII.—Chart showing the relations between corresponding values of the increments of specific resistance, hydrostatic pressure, and volume compression in case of mercury and a concentrated solution of zinc sulphate 76
XXVIII. Fig. 1. Time contraction of superheated silicated water 80
Fig. 2. Contraction and compressibility of silicated superheated water 80
XXIX. Fig. 1. Successive isothermals of superheated silicated water. 24° and 185° 82
Fig. 2. Relation of compressibility and contraction of superheated silicated water 82
Fig. 3. Time contractions of superheated silicated water 82
Fig. 4. Compressibility of paraffin and water compared 82

Digitized by Google

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF CHEMISTRY AND PHYSICS,
Washington, D. C., July 31, 1891.

SIR: I have the honor to transmit herewith the manuscript of a report by Dr. Carl Barus on "The Compressibility of Liquids," and to request that it be published as a bulletin of the U. S. Geological Survey.

Very respectfully,

F. W. CLARKE,
Chief Chemist.

Hon. J. W. POWELL,
Director U. S. Geoloical Survey.

Digitized by Google

Digitized by Google

PREFACE.

The present volume is the outgoing installment of certain researches on the thermodynamics of liquids now in progress at this laboratory. The results are exhibited in four sections. In the first of these I endeavor to circumscribe the relation between the volume changes of a fluid, in their dependence on pressure and on temperature, fusion effects being excluded. In the second I describe the volume lag (hysteresis), identify it as a limit case of the phenomenon of viscosity, and discuss its fundamental bearing on the molecular structure of matter. In the third section (chapter II of this book) I submit an electric method by which the phenomenally small compressibility of metals can be studied with a facility unattainable in mere volume measurement. In the fourth part (chapter III), finally, the compressibility of water above 100° is shown, particularly in relation to the solvent action of water on glass, and to the contraction of liquid bulk due to such action. In preparing the work for publication it was expedient to add the data on lag phenomena to my second bulletin on the viscosity of solids, soon to appear. The other matter is contained in the present volume.

Chapter IV has been added as an illustration of the easy application of the results deduced in chapter III to industrial problems.

I am aware that the subject of compressibility has to a considerable extent engaged the attention of Maj. J. W. Powell. The present work, however, was suggested, and in its general scope and character sharply outlined, by Mr. Clarence King, as will appear from a perusal of the geological inferences to which the present results are tributary. The experimental methods and discussions are mine; and purely physical inferences are, as a rule, given on my own responsibility.

The casual reader may ask, What has the behavior of complex organic matter and of liquid metal to do with geology? To such a one I may reply: It is now generally conceded by the clearest thinkers that the crust of the earth is underlain by a liquid stratum, and that most surface phenomena of upheaval and subsidence are in some way (regarding which the clear thinkers by no means agree) referable to this liquid. Now, until quite recently the topography of the thermodynamic surface of fluids has been altogether unknown. Mathematicians like J. Willard Gibbs have done much toward mapping out its possible contours. But the experimental facts were vague and useless. To endeavor to obtain these from rock magmas, which can be operated on

only under formidable difficulties, would at the present stage of research be manifestly absurd. Hence other substances of more definite character and more convenient fusing points are appropriately selected for examination; and the observer is throughout his work stimulated by the belief that an available analogy in the thermodynamic behavior of liquid matter in general, whether fusing at temperatures high or low, is not beyond the province of probability. The reader who is willing to peruse the following chapters with me may find evidence here and there that the suggestion of an analogy is not unreasonable.

Since the following work was done I have succeeded in constructing a screw compressor by aid of which 2,000 atmospheres may be applied with facility. I have also constructed a gauge by which these pressures may be accurately measured. The general adjustment is such that all necessary electric insulation of different parts of the apparatus is provided for, and most of the measurements may, therefore, be made electrically. With this apparatus I hope to subject the data which the following pages have laboriously shaped to a direct and more satisfactory test.

CARL BARUS.

WASHINGTON, *January, 1889.*

Digitized by Google

THE COMPRESSIBILITY OF LIQUIDS.

By Carl Barus.

CHAPTER I.

FLUID VOLUME: ITS DEPENDENCE ON PRESSURE AND TEMPERATURE.

INTRODUCTION.

1. The present chapter purposes to investigate the probable contours of the isothermals and the isometrics of liquid matter, in so far as this can be done with the means now at my disposal.

2. *Literature of compressibility.*—The literature of the subject has recently been critically digested by Tate[1]. Excellent excerpts are often to be found in the Fortschritte der Physik, so that I may content myself with brief mention. The work of Canton (1762–1764), Perkin (1820–1826), Oersted (1822), Colladon and Sturm (1827), Regnault (1847), Grassi (1851), Amaury and Descamps (1869), is discussed in most text books. Since that date the contributions have been manifold and are fast increasing. I shall, therefore, principally confine myself to papers in which volume changes produced by the simultaneous action of both pressure and temperature are considered.

Setting aside the literature[2] of critical points, which is too voluminous for discussion here, the work of Cailletet[3] is first to be noticed as introducing a long range of pressures (700 atmospheres). Amagat's[4] early work contains a larger temperature interval (0° to 100°), but applies for pressures below 9 atmospheres. The results are discussed in reference to Dupré's[5] equation. Passing Buchanan's[6] and Van der Waals's[7] results for the compressibility of water and of solutions, I came to an exceedingly important step in the subject made by Lévy,[8] though he had been considerably anticipated by Dupré.[9]

Lévy seeks to prove that the internal pressure of a body kept at constant volume is proportional to its temperature, which follows thermodynamically if the internal work done by heating is a volume function only or if specific heat in case of constant volume is a temperature func-

[1] Tate: Properties of Matter.
[2] See Landolt and Börnstein's Physikalisch-chemische Tabellen, Berlin, J. Springer, 1883, p. 62.
[3] Cailletet: C. R., vol. 75, 1872, p. 77.
[4] Amagat: C. R., vol. 85, 1877, p. 27. 139; Ann. ch. et phys., vol. 11, 1877, p. 520.
[5] Dupré: C. R., vol. 59, 1864, p. 490; ibid, vol. 67, 1868, p. 392.
[6] Buchanan: Nature, vol. 17, 1878, p. 439.
[7] Van der Waals: Beiblätter, vol. 1. 1877, p. 511.
[8] Lévy: C. R., vol. 87, 1878, pp. 449, 488, 676, 554, 649, 826.
[9] Dupré: Théorie mécanique de la chaleur, 1869, p. 51.

Digitized by Google

tion only. The position of Lévy is sharply antagonized by H. F. Weber,[1] Boltzmann,[2] Clausius,[3] and Massieu.[4] See below.

Amagat's[5] important work on the compression of gases may be mentioned because of its important bearing on methods of pressure measurement. In two critical researches Mees[6] perfects Regnault's piezometer and redetermines the compressibility of water. Tait[7] and his pupils, Buchanan,[8] Marshall, Smith, Omond,[9] and others, carry the inquiry of compressibility and maximum density of water much further, and the data are theoretically discussed by Tait. Pressures as high as 600 atmospheres are applied. Solutions of salt and alcohol are also tested. Pagliani,[10] Palazzo, and Vicentini,[11] using Regnault's piezometer, publish results for water and a number of other substances, mostly organic. They also examine mixtures. Temperature is varied between 0° and 100°, and the results are considerably discussed and utilized to show that Dupré's formula is only approximate. De Heen,[12] who has spent much time in studying volume changes of liquids, deduces a formula of his own, chiefly in reference to the thermal changes of compressibility. The theoretical results are tested by many experiments.

The research which Amagat[13] published at about this time is remarkable for the enormous pressure applied hydrostatically (3,000 atmospheres). Ether and water are operated on. In later work[14] these researches are extended to other liquid substances, with the ulterior object of finding a lower critical temperature. The behavior of water is fully considered. Grimaldi[15] critically discusses the earlier work on the maximum density of water. He[16] also examines the volume changes produced in a number of organic substances by temperature (0° to 100°), and pressure (0 to 25 atmospheres), and finds both Dupré's and De Heen's formulæ insufficient.

In further discussion he[17] also shows the insufficiency of Konowalow's[18] formula. At this stage of progress the points of view gained in the

[1] H. F. Weber: C. R., vol. 87, 1878, p. 517.

[2] Boltzmann: C. R., vol. 87, 1878, pp. 593, 773.

[3] Clausius: C. R., vol. 87, 1878, p. 718.

[4] Massieu: C. R., vol. 87, 1878, p. 731.

[5] Amagat: C. R., vol. 89, 1879, p. 437; ibid., vol. 90, 1880, pp. 863, 995; ibid., vol. 91, 1880, p. 428, and elsewhere.

[6] Mees: Beiblätter, vol. 4, 1880, p. 512; vol. 8, 1884, p. 435.

[7] Tait: Challenger Reports, vol. 2, 1882, appendix, pp. 1 to 40; Nature, vol. 23, 1881, p. 595; Proc. Roy. Soc. Ed., vol. 12, 1883-'84, p. 757; ibid., vol. 13, 1884-'85, p. 2; ibid., vol. 11, 1882-'83, p. 813; ibid., vol. 12, 1883, pp. 45, 223, 226.

[8] Buchanan: Proc. Roy. Soc. Ed., vol. 10, 1880, p. 697.

[9] Marshall, Smith, and Omond: Proc. Roy. Soc. Ed., vol. 11, 1882, pp. 626, 809.

[10] Pagliani and Palazzo: Beiblätter, vol. 8, 1884, p. 795; *ibid.*, vol. 9, 1885, p. 149.

[11] Pagliani and Vicentini: Beiblätter, vol. 8, 1884, p. 794; Journ. de phys. (2), vol. 30, 1883, p. 461.

[12] De Heen: Bull. Soc. Roy. Belg. (3), vol. 9, 1885, p. 550.

[13] Amagat: C. R., vol. 103, 1886, p. 429.

[14] Amagat: C. R., vol. 104, 1887, p. 1159; ibid., vol. 105, 1887, pp. 165, 1120; Journal d. phys. (2), vol. 8, 1889, p. 197.

[15] Grimaldi: Beiblätter, vol. 10, 1886, p. 338.

[16] Ibid., vol. 11, 1887, pp. 136, 137, 138.

[17] Grimaldi: Zeitschr. f. phys. Chem., vol. 2, 1888, p. 374.

[18] Konowalow: Zeitschr. f. phys. Chem., 2, 1888, p. 1.

Digitized by Google

extensive researches of Ramsay and Young[1] throw new light on the subject. They prove experimentally that, if pressure, p, and temperature, θ, vary linearly ($p = b\theta - a$), the substance operated on does not change in volume. The substances tested are ether, methyl and ethyl-alcohol, acetic acid, and carbon dioxide. Exceptional results for the case of acetic acid and nitrogen tetroxide are referred to dissociation. Utilizing James Thomson's[2] diagram they point out that the locus of the isothermal minima and maxima intersects the locus of maximum vapor tensions at the critical point. They show this to be the case for ether. Fitzgerald,[3] reasoning from Ramsay and Young's results, proves that for such liquids as obey the linear law specific heat must be a temperature function only, and internal energy and entropy must be expressible as the sum of two terms, one of which is a temperature function only and the other a volume function only. Thus Fitzgerald and Ramsay and Young arrive at the same position from which Dupré and Lévy originally started. My own work was brought to a conclusion before I had read the above researches; it was therefore specially gratifying to me to find my results according with those of Ramsay and Young. The data which I give apply emphatically for liquids, that is, for substances very far below the critical temperature. My pressures are, therefore, over six times as great as those of the English chemists. In case of thymol and of para-toluidine I even observed 25° and 15° below the respective melting points (under-cooling). Furthermore, my method of discussion is different. Fitzgerald,[4] has further applied Clausius's[5] equation to a discussion of Ramsay and Young's results. Sarrau[6] similarly endeavored to adapt Amagat's data. Dickson[7] has digested Andrews's data. Tait,[8] who is still actively at work on high pressures, has recently made publication on the effect of dissolved substances on internal pressure.

3. *Literature of heat expansion.*—A few words relative to thermal expansion of liquids, which enters incidentally into the present paper, may be added. Many formulæ have recently been devised or tested by Avenarius,[9] De Heen,[10] Mendeleeff,[11] Thorpe and Rücker,[12] Jouk,[13] and others,[14] not to mention older observers. None of the forms seem to be

[1] Ramsay and Young: Phil. Mag. (5), vol. 23, 1887, p. 435; ibid., vol. 24, 1887, p. 196; Proc. Roy. Soc. Lond., vol. 42, 1887. p. 3.

[2] James Thomson: Phil. Mag., vol. 43, 1872, p. 227; Nature, vol. 9, 1873, p. 392.

[3] Fitzgerald: Proc. Roy. Soc., vol. 42, 1887, p. 50.

[4] Ibid., p. 216.

[5] Clausius: Wied. Ann., vol. 9, 1880. p. 337.

[6] Sarrau: C. R., vol. 94, 1882, pp. 639, 718, 845; ibid., vol. 101, 1885, p. 941.

[7] Dickson: Phil. Mag., vol. 10, 1880, p. 40.

[8] Tait: Challenger Reports, Phys. and Chem., vol. 2, part 4, 1888; Proc. Roy. Soc. Edinb., vol. 15, 1888, p. 426.

[9] Avenarius: Mél. phys. Ac. St.-Petersb., vol. 10, 1877, p. 607; Beiblätter, vol. 2, 1878, p. 211; ibid., vol. 8, 1884, p. 806.

[10] DeHeen: Bull. Ac. Roy. Belg. (3), vol. 4, 1882, p. 526; Journ. Chem. Soc., vol. 45, 1884, p. 408.

[11] Mendeleeff: Chem. Ber., vol. 17, 1881, p. 129; Beiblätter, vol. 8, 1884, p. 806.

[12] Thorpe and Rücker: Journal Chem. Soc., vol. 45, 1884, p. 135.

[13] Jouk: Beiblätter, vol. 8, 1884, p. 808.

[14] Rosenberg: Journ. d'Almeida, vol. 7, 1878, p. 350.

Digitized by Google

satisfactory when long ranges of temperature are introduced. This is shown in a critical research by Bartoli and Stracciati[1] relative to Mendeleeff's and Thorpe and Rücker's formulæ and by the discussion between Mendeleeff and Avenarius.

4. *Remarks on the literature.*—Surveying the forementioned researches as a whole, it appears that at their present stage more work has been spent on the compressibility of water than the exceptional behavior of this substance justifies. In other words, the volume-pressure-temperature changes of the great majority of liquids probably conform closely to a general thermodynamic law discovered by Dupré and Lévy, and by Ramsay, Young, and Fitzgerald, severally. It is therefore first desirable to find experimentally the full importance of this law, and then to interpret exceptional cases with reference to it. Again, it appears that researches in which long-pressure ranges are applied simultaneously with long-temperature ranges are urgently called for, and that it is from such work that further elucidation of this important subject may be obtained.

Among pressure experiments the late researches of Amagat stand out by their originality and importance. One can not but admire the experimental prowess which has enabled him to penetrate legitimately into a region of pressures incomparably high without lowering his standard of accuracy.

Special mention must be made of the celebrated papers of J. Willard Gibbs,[2] by whom the scope of graphic method in exhibiting the thermodynamics of fluids has been surprisingly enlarged. The terms *isometric*, *isopiestic*, *isothermal*, *isentropic*, etc., are used in the present paper in the sense defined by Gibbs (loc. cit., p. 311).

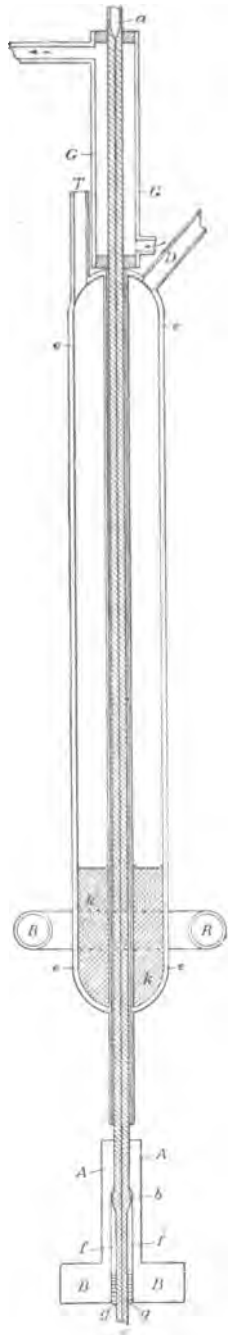
APPARATUS.

5. *Force pump and appurtenances.*—In making the experiments detailed in the following pages I used a large Cailletet compression pump, in the form constructed both by Ducretet, of Paris, and by the Société Génevoise. Its efficiency is 1,000 atmospheres. It is made to be fed with water, but I found that by using thin mineral sperm oil it was possible to facilitate operations, because there is less danger of rusting the fine polished steel parts of the machine. The pump consists of two parts: the pump proper and the strong cylindrical wrought-iron trough in which the compression tubes are screwed. This trough is cannon-shaped, its axis vertical, and the open end uppermost. Pump and trough are connected by strong phosphor-bronze tubing, and similar tubes lead to the large Bourdon manometer, by which the pressures are measured.

6. *Pressure tube and appurtenances.*—The substance to be tested is inclosed in capillary tubes of glass of very fine bore (0·03^{cm} or less) and

[1] Bartoli and Stracciati: Beiblätter, vol. 9, 1885, p. 510.
[2] J. W. Gibbs: Trans. Conn. Acad., II (2), 1873, pp. 309, 382.

Digitized by Google



Capillary tube, with appurtenances, for measuring the compressibility of liquids.
(Scale, one-third.)

Digitized by Google

Digitized by Google

about 0·6^{cm} thick, such as are often used for thermometers. In my earlier experiments I had cylindrical bulbs blown near the middle of these tubes, and to give them greater strength a cylinder of solder was cast in brass around the bulb. This arrangement is very much more delicate than a plain capillary; but the tubes broke under pressures exceeding 200 atmospheres. For this reason, and because of the difficulty of adjusting a suitable vapor bath, the bulb tube was rejected in favor of a straight capillary tube. The length used was about 50^{cm} or 60^{cm}. To insert them into the trough the solid glass of the capillary tube *abc*, Pl. I, was swelled or bulged at *b*, about 5^{cm} from one end, and then pushed through an axially perforated steel flange *ABBA*, in which it fitted snugly. The bulged end and the flange faced the inside of the trough, so as to be acted against by the pressure. To seal the tube in the steel flange fusible metal *ff* was cast around it at the bulge, and the joint was then further tightened by a thick coating of marine glue, *gg*. A strong hollow nut of iron, surrounding both the lower end of the tube and the flange, fastened it to the trough, by forcing it against a leather washer. When completely adjusted the capillary tube projected about 40^{cm} or 50^{cm} clear, above the trough. Pressure was communicated through the oil of the pump to the mercury in the trough, which was in immediate connection with the open lower end of the capillary tube.

7. *Method of charging the tube.*—A thread of the solid substance to be acted on was introduced into the capillary between threads of mercury. This is a difficult operation, requiring much care. My first method was to pump out the air with a Sprengel pump; then to let the substance run down into it from a reservoir at the top of the tube by appropriate fusion. This method was far from perfect, and I found it almost impossible to insert the two mercury threads at the right place. After a variety of other trials of this kind I finally abandoned the vacuum method in favor of the following: Wide glass tubes (reservoirs) were fused both to the upper and the lower end of the capillary. The wide tube at the lower end was bent nearly at right angles to the axis of the capillary. I then poured mercury into the bent end, a continuous thread of which could be made to run quite through the capillary by properly inclining it. The substance was introduced into the upper reservoir and fused, care being taken to boil out the air, so that eventually the thread of mercury came directly in contact with the fused substance. The capillary is now less inclined. Mercury thread slowly ran back toward the lower end, followed by a thread of the substance, kept fused by applying a burner on the outside of the tube. This operation was repeated a number of times, so as to cleanse the tube with the substance and expel the little bubbles of air which might adhere to the walls of the capillary canal. Finally, when the mercury thread, capped by the thread of substance, was of suitable length, a globule of mercury was also put into the upper reservoir, covered by the fused substance

Digitized by Google

in such a way as to exclude air. By a quick motion the tube was then placed in nearly a vertical position, whereupon the lower thread of mercury ran down farther, followed by the thread of substance and an upper thread of mercury. The tube was now again brought back to the former position, with the thread of substance between the two threads of mercury, nearly in place. At this point the upper reservoir was cleansed with bibulous paper and, to seal it, filled with fused paraffine, in such a way that no air was left at the upper end of the upper mercury thread. Gently inclining the tube again, paraffine ran into the capillary, following the other threads. When the paraffine thread was sufficiently long the tube was left to itself till the threads solidified. During the whole operation the capillary tube must be kept heated. Considerable skill is required to obtain a properly charged tube, and the method must be varied, of course, when volatile liquids are to be introduced. It is not advisable to seal the upper end of the glass by fusing it, because the strains introduced during cooling greatly diminish the strength of the tube. The paraffine thread must be kept solid by a cold-water jacket, *GG*. Under these conditions its viscosity is too great to admit of its being forced out of the capillary tube by any pressure (1,000 atmospheres) compatible with the strength of the tube. Faultless adhesion of the paraffine to the glass is essential. In case of hygroscopic substances, therefore, this method fails, and the tube must be sealed in other ways.

Passing from the top to the bottom of the charged capillary one therefore encounters the following succession of threads: Paraffin (5^{cm}), mercury (5^{cm}), substance (20^{cm}, depending on its compressibilty however; in case of ether a thread 1^{cm} long is sometimes essential), mercury (25^{cm}), in communication with the mercury of the trough. Measurements are therefore made by observing the distance apart of the lower meniscus of the upper thread of mercury, and the upper meniscus of the lower thread, with Grunow's cathetometer. When the adjustment is perfect the motion at the upper thread is nearly zero. Any sliding here is fatal, and the tube must be readjusted when this occurs.

8. *Method of heating.*—To heat the sample to any required temperature I surrounded the capillary tube, *abc*, with one of my closed boiling tubes,[1] *eeee*, Pl. I, of clear glass.

By connecting the latter with a condenser at *D*, the ebullition may be prolonged for any length of time. The whole thread of the substance is thus virtually exposed in a vapor bath. Methyl alcohol (65°), water (100°), aniline (185°), and diphenylamine (310°) are available for boiling points. The position of these liquids is shown at *kk*, and they are heated by Dr. Wolcott Gibbs's ring burner, *R*, *R*. A thermometer is inserted at *T*. At high temperatures it is of course necessary to

[1] Cf. Bulletin, U. S. Geol. Survey, No. 54, 1889, pp. 86 to 90.

Digitized by Google

jacket the boiling tube appropriately with asbestos wicking, leaving only two small windows exposed through which the substance may be seen with the telescope. When the tube is fully heated it is clear, and condensation takes place only in the condenser. By adjusting suitable white and black screens with reference to the line of sight the image of the meniscus may be sharpened. Intermediate temperatures are reached by boiling the substances under low pressures. For this purpose it is merely necessary to attach the open end of the condenser to Prof. R. H. Richards's[1] pneumatic exhausting pump. The temperature is read on the thermometer at *T*.

It is scarcely necessary to state that the manipulations are difficult throughout, and that with the best of care breakage of tubes is a frequently recurring annoyance. Special attention must be given to obtain capillary tubes well annealed; otherwise internal strains add themselves to external strains and the strength of the tube is insufficient. Vapor baths must not be removed until the tube is thoroughly cold. With the best of care a tube will not outlast many series of experiments, for as pressure continues the glass undergoes a change very analogous to permanent set, so that eventually a tube may be broken at less than one-half the original test pressure.

9. *Pressure measurement.*—As is easily seen the method of experiment must necessarily be such that temperature is kept constant while pressure is varied at pleasure. To measure pressures I used a Bourdon gauge[2] graduated in steps of 10 atmospheres each, up to 1,000. So graduated, the gauge registers smaller differences of pressure than can be measured in terms of the volume changes of the liquid in the capillary tubes. Hence the gauge is suitable.

To test the gauge[3] I compared it with a similar gauge graduated as far as 300 atmospheres and found the lack of accordance no larger than the error of reading. Again I compared the gauge indications with the changes of electrical resistance of mercury under identical conditions of pressure, with results equally satisfactory, as will be explained in the next chapter.

10. Curious results were obtained on comparing the gauge with a closed manometer, the essential part of which was a capillary tube containing air. The results calculated with reference to Boyle's law, i. e., for isothermal expansion, were found to be wholly discrepant. The difficulty was interpreted by computing with reference to Poisson's law, i. e., for adiabatic expansion. Some results are given in Table 1:

[1] Richards: Trans. Am. Inst. Mining Eng., vi, 1879, p. 1.

[2] I think Prof. Tait, who has constructed other gauges based on Hooke's law, underestimates the ingenuity of Bourdon's gauge; and I believe that, either by increasing the number of coils or by suitably adjusting a mirror index, the gauge can be made serviceable without a multiplying gear. Read off directly, the only limit to the scientific efficiency of the gauge is the viscosity of the Bourdon tube.

[3] I have since compared the gauge directly with Amagat's "Manomètre à pistons libres" and found my surmises substantiated.

Digitized by Google

p, v, k denotes pressure, volume, and the specific heat ratio, respectively. The error at $p = 100$ is due to the time lost in making the measurement, since it is here that volume changes are large and require special adjustments of telescope.

TABLE 1.—*Compressibility of air. Test of gauge.*

p	v	log $v^k p$	v	log $v^k p$
100	1,030	6·25	1,040	6·25
200	550	6·16	552	6·17
300	400	6·15	393	6·14
400	329	6·15	324	6·16
500	.....	.....	285	6·16

It appears that in case of quick manipulation this method is available for the measurement of k, particularly with reference to its variation with pressure. It appears also that when work is done on gases much time must be allowed in capillary tube experiments before the changes of volume obtained can be pronounced isothermal.

Since the gauge is based on Hooke's law, errors of the zero point are eliminated by working between indicated pressures and taking differences of reading. So far as relative pressure data are concerned it is then merely necessary that the attached dial and mechanism be virtually a scale of equal parts.

Finally, I compared the Bourdon gauge with a form of Tait gauge of my own, in which the volume expansion of a suitable steel tube is measured externally. Leaving further description to be given elsewhere, I will here insert a mere example of the results obtained. N. G. denotes the reading of the new gauge, an arbitrary scale being attached.

TABLE 2.—*Comparison of gauges.*

Bourdon.	N. G.	Bourdon.	N. G.
0	0	600	1045
100	160	700	1210
200	335	800	1370
300	520	900	1530
400	690	1000	1700
500	870		

Constructing the data graphically and remembering that all deviations are to be apportioned between the gauges, it appears that the error must everywhere be less than 10 atmospheres in most unfavorable cases.

No stress was placed on the absolute correctness of the standard atmosphere employed. The results sought follow equally well for an approximate standard, correctly multiplied.

Digitized by Google

11.—*Volume changes of the glass tubes.*—Prof. Tait[1] has given the following expression for the volume increment of a cylinder, subjected to internal hydrostatic pressure:

$$\frac{\Pi a_0^2}{a_1^2 - a_0^2}\left(\frac{1}{k} + \frac{a_1^2 1}{a_0^2 n}\right)$$

where Π is the pressure, $\frac{1}{k}$ and n the compressibility and the rigidity of the glass, and where a_0 and a_1 are the inner and the outer radius of the tube, respectively.

The internal and external radii of my tubes were 0·015^{cm} and 0·3^{cm}, respectively. It is easily seen that in case of so small a ratio the term of the above expression involving the compressibility of glass may be neglected with no greater error than a few tenths per cent. Hence, if proper value[2] of n be introduced and pressure be measured by atmospheres, the above expression reduces, approximately, to $4\Pi 10^{-6}$.

Unfortunately this correction is by no means negligible[3] and may in unfavorable cases amount to as much as 5 per cent of the corresponding volume decrement of the liquid to be tested. The case is worse; most of the experiments are to be made at temperatures between 60° and 300°, for which interval the rigidity of glass can not be said to be known. To determine it myself was out of the question. Hence, instead of introducing arbitrary considerations, I resolved to neglect the correction altogether in favor of direct test experiments with mercury and with water.

12. *Mercury tests.*—The compressibility of mercury is too small to be amenable to the present method of measurement. Hence, since its compressibility is known, it is well adapted for testing the errors of the apparatus.

In Table 3 I have given the temperature, θ, and the length of the mercur thread, L, observed; also the volume decrement v/V per unit of volume, for each pressure p, as well as the corresponding mean compressibility β. Many methods were tried; best results were obtained for a thread of mercury inclosed between end threads of melted paraffin. At the low temperature, 30°, the lower thread was alcohol. The first column, v/V, was obtained by increasing p from 20 to 400 atmospheres, the second by decreasing p from 400 to 20 atmospheres, though the data given are means of a number of such measurements. Great care must be taken to keep the mercury thread free from adhering bubbles of air or volatile liquid (alcohol, for instance). At high temperatures these globules expand and may utterly vitiate the results, as I found in more than one instance.

[1] Tait: Challenger Reports, 1882, Appendix, p. 29.

[2] Everett: Units and Physical Constants, Macmillan, 1879, p. 53.

[3] Since the sectional expansion alone enters, the correction is smaller than the above estimate.

Digitized by Google

TABLE 3.—*Compressibility of mercury.*

θ, L	p	$\frac{v}{V}\cdot 10^3$	$\frac{v}{V}\cdot 10^3$	$\beta\times 10^6$
30° 16·7cm	20	0·0	0·0	.....
	100	0·0	0·3	2
	200	0·3	0·3	2
	300	0·9	0·6	3
	400	1·8	1·2	4
65° 16·8cm	20	0·0	0·0	.....
	100	1·2	0·0	8
	200	2·1	2·0	14
	300	2·4	1·7	8
	400	3·0	2·9	8
100° 16·9cm	20	0·0	0·0	.....
	100	0·9	0·6	10
	200	1·2	1·8	9
	300	2·4	1·8	8
	400	2·7	3·0	8
185° 17·1cm	20	0·0	0·0	.....
	100	1·0	1·2	14
	200	2·3	2·2	13
	300	2·6	2·6	9
	400	4·5	3·9	11

ANOTHER THREAD, BETWEEN PARAFFIN.

185° 19·3cm	10	0·0	0·0	.....
	100	0·8	0·8	10
	200	2·9	3·0	17
	300	3·7	3·9	14
	400	4·9	4·5	13
310° 19·7cm	20	0·0	0·0	.....
	100	1·0	1·4	15
	200	2·6	2·6	14
	300	3·9	4·1	15
	400	5·3	5·2	14

Some of these results are shown in Pl. II, pressure being the abscissæ and volume decrements, $10^3\times v/V$ the ordinates. This figure should be compared with the subsequent figures for organic substances.

Table 3 is reassuring. From the known low-temperature compressibility of mercury[1] it appears that the error of β, made by neglecting Tait's correction, is about 10^{-6}, and that it is not greater than the unavoidable errors of measurement. Again, since the compressibility of the organic substances to be examined is in almost all cases much greater than 60×10^{-6}, the said error of β is not much above 2 or 3 per cent.

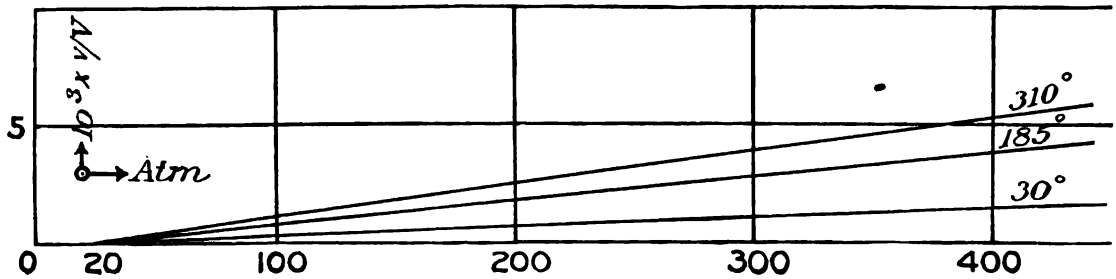
By comparing table 3 with tables 4 to 18 (δ) it will be seen that the results at high temperatures are even more favorable.

Similar results were obtained for water, which may therefore be omitted here.

13. *Isothermals and adiabatics.*—To obtain the isothermals of the compressed liquids it would be necessary to wait a long time after each

[1] Everett: Loc. cit., pp. 52, 53. Amagat: C. R., vol. 108, 1889, p. 228; Journ. de phys. (2), vol. 8, 1889, p. 197. Tait: Loc. cit.

Digitized by Google



Approximate compressibility of mercury.

Digitized by Google

Digitized by Google

compression. But by so doing, at high temperatures, the tube would be seriously weakened in virtue of the diminished viscosity[1] of the material, if not even distorted. It appears, moreover, that the distinction between isothermal and adiabatic compression is beyond the scope of the present method of volume measurement. Finally, since the substance is in the form of *an extremely fine* (capillary) *filament*, the conditions are exceptionally favorable to isothermal expansion, for the excess of heat of the thread is at once imparted to the thick walls of the capillary tube. For this reason the discrepancy is not of such serious moment as would otherwise be the case. Hence I made my observations by varying pressure from 20 atmospheres to the maximum and then from the maximum back to 20 atmospheres, with only such allowance of time as was necessary for observation at the successive stages of pressure.

Near the critical temperature only is the distinction between isothermal and adiabatic decidedly larger than the errors of volume measurement.

The chief reliance was placed on the constancy of the fiducial zero. The volume increments must be identical, no matter whether they are observed during the pressure-increasing or during the pressure-decreasing march of the measurements.

14. *Thermal expansion.*—My measurements of thermal expansion are incidental; but they are necessary for the coordination of results. Without a bulb-tube such measurements are not very accurate, and the inaccuracy is much increased by the breaking off of the ends of the mercury thread whenever the substance operated on solidifies. In passing from one constant temperature to another an exchange of boiling tubes is to be made, and it is almost impossible to keep the substance in the capillary tube fused during the whole of the time for readjustments. On solidification the substances contract as much as 10 per cent. The mercury thread is therefore forced into the vacuities in the axis of the solid thread. After fusing again, it will be found that the lower column of mercury has broken into distinct little pieces, sometimes in great number, alternating with little threads of the substance. All of these must be measured, an operation which is not only excessively tedious, but makes the expansion measurement very inaccurate. For the same reason no correction need be added for the expansion of the glass. The error thus introduced is usually small, and not greater than 2 or 3 per cent in unfavorable cases of low temperature. See Tables 5 et seq. At high temperatures such a correction would be arbitrary, for the reason given in § 11. In these cases, however, it is probably altogether negligible, particularly so near the critical temperature.

[1] It is interesting to note that continued pressure weakens glass *gradually*, but without any apparent change of volume. The conditions of rupture may not be reached till after the lapse of much time. The tubes used must be of well annealed glass. Any temper strain is sure to cause rupture at relatively low pressures.

Digitized by Google

EXPERIMENTAL RESULTS.

15. *Explanation.*—My first results were obtained with capillary tubes, the middle part of which had to be blown out into a bulb. Around this a jacket of solder was cast and the whole contained in a brass tube. I found, however, that breakage took place from pressures of only 200 atmospheres, that corrections for glass expansion could not be estimated, and that the adjustment of the bath for constant temperature was unsatisfactory. I will therefore omit the data obtained, as they only corroborate the following results. Having thus found that compressibility would be measureable in cylindrical tubes, my next experiments were made in somewhat wider and thicker tubes than those discussed in §6. They have an advantage inasmuch as a filamentary thermocouple can be drawn through the tube without vitiating the volume measurement; but they broke under 300 atmospheres and were not conveniently thin for the thermal bath. These results are also rejected here, but will be cited in § 42, where the direct observations of contraction on cooling under pressure are exhibited. Finally I made use of the thermometer capillaries already described, § 6. In the earlier work (naphthalene, monochlor acetic acid), I did not introduce the upper thread of mercury, sealing the tube with a solid cold thread of the substance of the sample. This introduces arbitrary errors at the point where solid and fused substances meet; for on increasing pressures some of the liquid will be converted into solid, thus decreasing the length of the column. The reverse takes place on removing pressures. Nor is it possible to measure the length of thread of substance accurately, since the point of meeting of solid and liquid rises as the heating continues or when the stationary distribution of temperature is interfered with. Hence the facility of charging the tube is not compatible with accuracy of measurement, and I give these results only because many subsequent trials made to repeat them failed through accidents.

The bulk of the following experiments were made as detailed in § 6.

Throughout the following tables L is the length of the thread of substance, at the temperature θ; v/V, the corresponding volume-decrement due to the acting pressure p. Finally, β is the mean compressibility between p_0, the initial pressure, and the pressure given. Values marked observed and calculated and other information in the tables will be discussed below, §34 et seq.

16. *Ether.*—My results for ether are given in Table 4. Manipulations were made exceedingly difficult because of some sulphur present in the liquid. This at once attacks the mercury and destroys the cohesion of the thread. Above 100°, the thermal expansion increases enormously, so that I found it necessary to operate with two threads, the long one for low temperature and the short one for 310°. The tubes were filled by the U-tube method, § 7.

For the reasons given the initial pressure could not be kept constant,

Digitized by Google

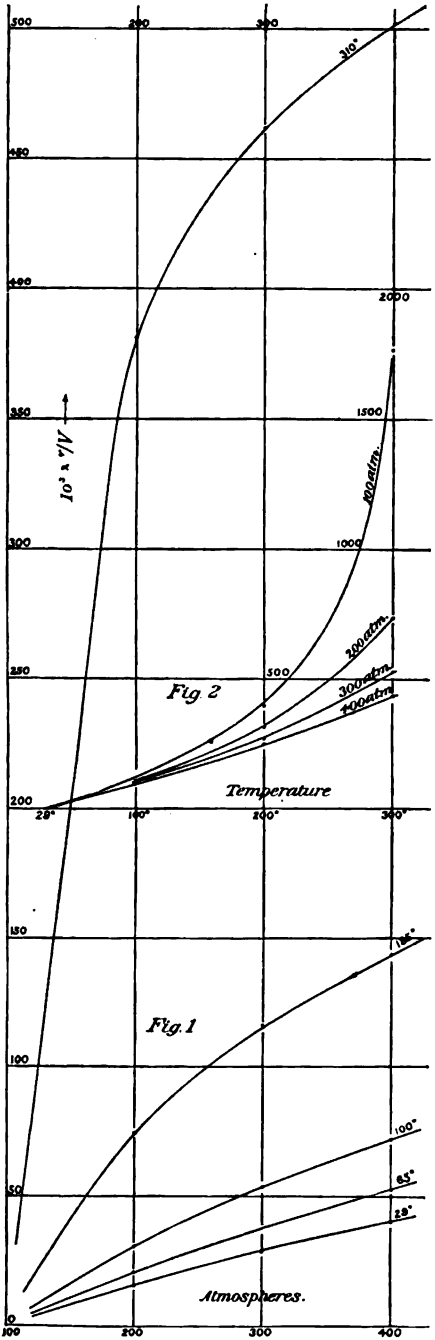


FIG. 1. Relative isothermals of ether. p_0=100 atmospheres, θ_0=29°
FIG. 2. Relative isopiestics of ether. p_0=100 atmospheres, θ_0=29°.

Digitized by Google

Digitized by Google

tubes not being long enough. Hence Table 5 has been computed, which all data are reduced to the uniform initial pressure, $p_0 = 100$ nospheres.

Table 6 finally shows the corresponding expansion data. It may be iced that, supposing the given conditions to continue, ether would se to expand at 1,100 atmospheres. These results are graphically eated in Pl. III, Fig. 1, of which the curves are isothermal volume rements referred to unit of volume, at the temperature given on the ve, and at the inital pressure $p_0 = 100$ atmosphcres. In Pl. III, Fig. have similarly given the isopiestic volume increments referred to t of volume at 29° and at the pressure given on the curve.

he two rows of results for $10^3 \times v/V$, given in tables 4, 7, et seq., e obtained during the pressure-increasing and the pressure-decreas- series of the experiments. This has already been explained in §13.

LE 4.—*Compressibility of ether. Direct measurements. B. P., 34°; critical temperature, 195°.*

L, θ	p	$\frac{v}{V} \times 10^3$	$\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Mean $\beta \times 10^6$ 0 to 400 atmospheres.
14·6cm 29°	20	0·0	0·0	.....	.....
	100	14·1	13·4	172	.....
	200	29·1	29·1	162	.....
	300	42·8	41·8	151	.....
	400	54·1	53·8	142	.....
15·5cm 64°	20	0·0	0·0	.....	.....
	100	20·1	19·7	248	.....
	200	39·7	41·0	224	.....
	300	57·1	56·8	203	.....
	400	71·6	71·9	189	.....
16·8cm 100°	10	0·0	0·0	.....	.....
	100	36·0	35·4	396	.....
	200	65·8	64·9	344	.....
	300	87·8	87·5	302	.....
	400	106·5	105·5	272	.....
21·8cm 177°	50	0	0	.....	.....
	100	80	80	1,600	.....
	150	122	.....	1,220	.....
	200	148	148	990	.....
	250	169	.....	845	.....
	300	186	186	745	.....
	350	200	.....	667	.....
	400	211	212	605	.....

SHORT FIBER, $L_{27} = 5{\cdot}34^{cm}$.

14·6cm 310°	100	0	0	.....	.....
	150	287	287	5,740	.....
	200	382	382	3,820	.....
	250	431	431	2,870	.....
	300	463	463	2,320	.....
	350	485	484	1,940	.....
	400	502	502	1,680	.....

Digitized by Google

TABLE 5.—*Compressibility of ether, referred to 100 atmospheres.*

θ, L	p	Observed. $\frac{v}{V}\times10^3$	$\beta\times10^6$	Computed. $\frac{v}{V}\times10^3$	Diff.$\times10^3$	$\vartheta\times10^6$	$\vartheta_0\times10^6$
29° 14·37cm	100	0·0	.....	0·0	.....	.....	.....
	200	15·6	156	15·4	+0·2	165	194
	300	28·9	145	28·9	·0	.....	.....
	400	40·8	136	40·9	— ·1	.....	.....
65° 15·18cm	100	0·0	.....	0·0	.....	.....	.....
	200	20·7	207	20·5	+ ·2	226	282
	300	37·7	189	37·8	— ·1	.....	.....
	400	52·8	176	52·8	± ·0	.....	.....
100° 16·25cm	100	0·0	.....	0·0	.....	.....	.....
	200	30·5	305	29·9	+ ·6	343	497
	300	53·6	268	53·4	+ ·2	.....	.....
	400	72·2	241	72·8	— ·6	.....	.....
185° 20·08cm	100	0·0	.....	0·0	.....	.....	.....
	200	74·1	741	71·5	+2·6	1,005	10,060
	300	115·5	577	114·7	+·8	.....	.....
	400	143·5	478	145·6	—2·1	.....	.....
310° *14·59cm	100	0	.....	0	.....	.....	.....
	200	382	3,820	383	—1	34,250	.....
	300	462	2,310	460	+2	.....	.....
	400	502	2,510	503	—1	.....	.....

*Second sample.

TABLE 6.—*Thermal expansion of ether* $\frac{v}{V}\times10^3$, *referred to 29°.*

Atm. =		100.	200.	300.	400.
θ =	29°	0	0	0	0
	65°	57	51	48	43
	100°	131	114	103	93
	185°	397	315	274	246
	310°	1,770	733	528	435

COMPUTED VALUES $\frac{v}{V}=ln\left(1-\beta(\theta-b)\right)^{-\tau,\beta}$. See § 41.

θ =					
	29°	— 9	— 5	— 6	— 4
	65°	59	50	45	40
	100°	136	112	100	89
	185°	389	305	266	232
	310°	1,750	869	690	562

17. *Alcohol.*—The alcohol used was not free from water, though commercially absolute. Table 7 contains the observations made for compressibility. The initial pressure had again to be changed at high temperatures. Hence I have computed Table 8, in which the initial pressure is uniformly 150 atmospheres. The corresponding values of thermal expansion are given in Table 9. Of the charts, Pl. IV, Figs. 1 and 2, the former are isothermal decrements, each referred to unit of volume at the initial pressure, 150 atmospheres, and at the temperature marked on the curve. Similarly the isopiestics, Fig. 2, are referred to unit of volume at 28° and at the pressure on the curve. The results

Digitized by Google

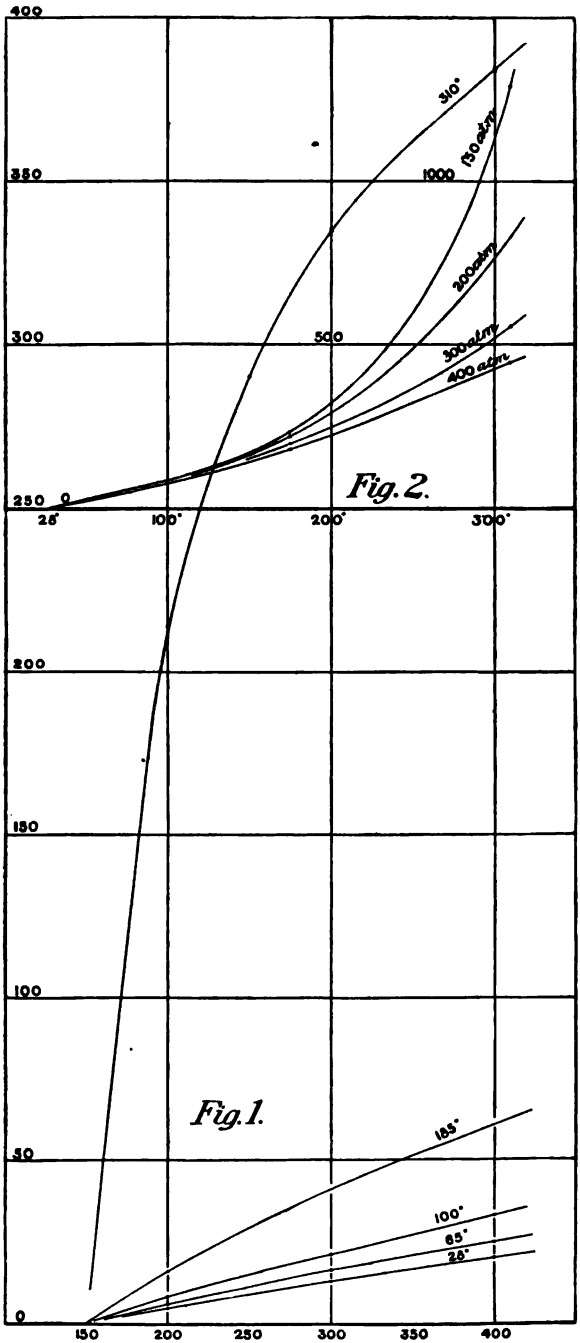


FIG. 1. Relative isothermals of alcohol. $p_0=150$ atmospheres, $\theta_0=28°$.
FIG. 2. Relative isopiestics of alcohol. $p_0=150$ atmospheres, $\theta_0=28$.

Digitized by Google

Digitized by Google

more satisfactory than ether, because a single thread only was used. constructing Tables 5 and 8 I had to sacrifice some observations. t it seemed better to do this than to reach the lower initial pressure more or less arbitrary hypotheses. The two sets of data (§ 16) are en side by side.

BLE 7.—*Compressibility of alcohol. Boiling point, 78°; critical temperature, 236°.*

L, θ	p	$\frac{v}{V}\times10^3$	$\frac{v}{V}\times10^3$	$\beta\times10^6$
9·58cm 27°	20	0·0	0·0	.....
	100	9·7	8·9	116
	200	18·6	17·8	101
	300	27·1	26·0	95
	400	34·1	33·6	90
9·93cm 63°	20	0·0	0·0	.....
	100	9·4	9·6	118
	200	20·2	20·6	113
	300	31·5	30·8	111
	400	40·0	39·5	104
10·49cm 100°	20	0·0	0·0	.....
	200	15·1	14·3	184
	300	28·4	29·1	160
	300	42·0	41·6	150
	400	52·9	53·1	140
12·25cm 180°	20	0·0	0·0	.....
	100	35·9	35·3	445
	200	67·1	66·6	372
	300	91·1	90·3	324
	400	110·0	110·0	290
21·75cm 310°	150	0	0	.....
	200	212	208	4,200
	250	289	291	2,900
	300	334	333	2,220
	350	363	364	1,820
	400	380	385	1,530

TABLE 8.—*Compressibility of alcohol, referred to 150 atmospheres.*

θ, L	p	Observed. $\frac{v}{V}\times10^3$	$\beta\times10^3$	Computed. $\frac{v}{V}\times10^3$	Diff. $\times10^3$	ϕ	ϕ_0
28° 9·45cm	150	0·0	.....	0·0	·0	.....	.....
	200	4·3	86	4·3	·0	89	101
	300	12·7	85	12·6	+·1	.....	.....
	400	20·2	81	20·2	·0	.....	.....
65° 9·78cm	150	0·0	.....	0·0	·0	.....	.....
	200	5·5	110	5·6	—·1	115	136
	300	16·4	109	16·0	+·4	.....	.....
	400	25·1	100	25·5	—·4	.....	.....
100° 10·27cm	150	0·0	.....	0·0	·0	.....	.....
	200	8·4	168	7·6	+·8	158	201
	300	21·6	144	21·5	+·1	.....	.....
	400	33·1	132	34·0	—·9	.....	.....
185° 11·62cm	150	0·0	.....	0·0	·0	.....	.....
	200	16·0	320	15·4	·6	331	598
	300	41·1	274	40·9	·2	.....	.....
	400	61·2	245	61·8	—·6	.....	.....
310° 21·75cm	150	0	.....	.....	.....	.....	.....
	200	211	4,200	219	— 8	13,880	.....
	300	335	2,220	330	+ 5	.....	.....
	400	384	1,530	385	— 1	.....	.....

Digitized by Google

TABLE 9.—*Thermal expansion of alcohol,* $\frac{v}{V} \times 10^3$, *referred to 28°.*

Atm. =		150	200	300	400
θ =	28°	0	0	0	0
	65°	35	35	31	30
	100°	87	82	78	73
	185°	229	217	195	178
	310°.	1,290	826	555	447

18. *Palmitic acid.*—The data are given in Tables 10 and 11, on a plan uniform with the above. Owing to accidents, two threads were observed; the first between 65° and 185°, and the second between 65° and 310°. At 65° solidification set in at 400 atmospheres. The necessary result is distortion of the curvature of the loci. Much difficulty was encountered because of breaks in the mercury thread. Hence the circumflexure in the isopiestics is probably an error of observation (Cf. Pl. v).

TABLE 10.—*Compressibility of palmitic acid,* $C_{16}H_{32}O_2$. *Melting point, 62°; boiling point, 350°.*

L, θ	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed. $\frac{v}{V} \times 10^3$	Diff. $\times 10^3$	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$
65° 10·72cm	20	0·0	0·0	.....	*0·0	0·0	91	93
	100	7·2	7·2	90	7·1	−0·1	.....	.....
	200	15·0	15·3	85	15·3	−0·1	.....	.....
	300	22·8	23·1	82	23·0	−0·1	.....	.....
	†400	31·1	31·1	82	30·1	+0·2	.....	.....
100° 17·16cm	20	0·0	0·0	.....	0·0	0·0	102	104
	100	8·1	8·1	101	7·8	+0·3	.....	.....
	200	16·9	16·3	93	16·9	−0·3	.....	.....
	300	25·5	25·5	91	25·4	+0·1	.....	.....
	400	33·3	33·3	88	33·2	+0·1	.....	.....
185° 18·50cm	20	0·0	0·0	.....	0·0	0·0	160	165
	100	12·1	12·1	151	12·1	0·0	.....	.....
	200	26·3	26·3	146	25·5	−0·2	.....	.....
	300	37·2	37·8	134	37·5	0·0	.....	.....
	400	48·2	47·7	127	48·5	−0·4	.....	.....

* Including the lower series for 65°. † Solidifying.

SECOND SAMPLE.

65° 14·63cm	20	0·0	0·0	.....	.....	.....	.....	.....
	100	6·5	6·9	84	.....	.....	.....	.....
	200	15·1	15·1	84	.....	.....	.....	.....
	300	22·9	22·3	81	.....	.....	.....	.....
	400	29·5	29·5	78	.....	.....	.....	.....
310° 17·54cm	20	0·0	0·0	.....	0·0	0·0	330	351
	100	23·4	24·6	300	23·7	+0·3	.....	.....
	200	47·4	48·3	265	47·5	+0·4	.....	.....
	300	66·3	67·9	240	67·2	−0·1	.....	.....
	400	82·6	84·3	220	83·8	−0·3	.....	.....

Digitized by Google

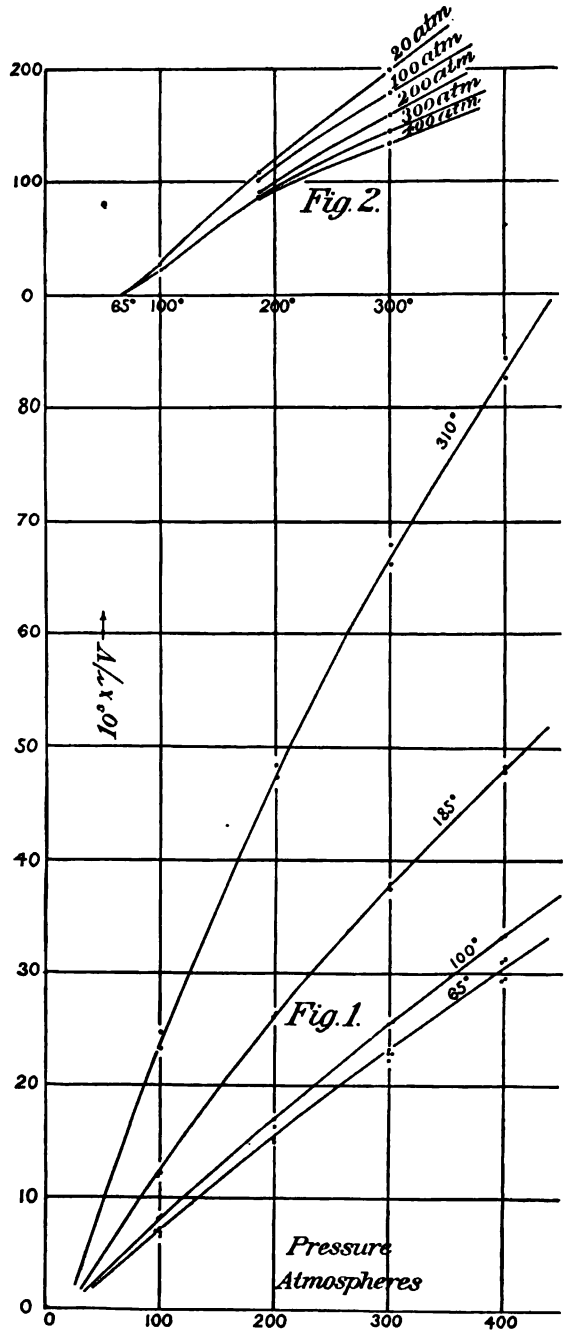


FIG. 1. Relative isothermals of palmitic acid. p_0=20 atmospheres, θ_0=65°

FIG. 2. Relative isopiestics of palmitic acid. p_0=20 atmospheres, θ_0=65°.

Digitized by Google

Digitized by Google

TABLE 11.—*Thermal expansion of palmitic acid,* $\frac{v}{V} \times 10^3$ *referred to 65°.*

Atm. =		20	100	200	300	400
θ =	65°	0	0	0	0	0
	100°	26	25	24	23	24
	185°	107	101	93	91	87
	310°	199	179	159	145	133

19. *Para-toluidine.*—The following data, Tables 12 and 13, and the diagrams, Pl. VI, were obtained for toluidine. A feature of these results is the circumflexure of the isopiestic increments in the undercooled part of their course. This is probably not an error, since it recurs again under similar conditions, in case of thymol, § 25. It may be noted that if contraction due to cooling under pressure continued at the same rate as shown in Table 13, there would be no volume change at 1,400 atmospheres. I found that to solidify the undercooled liquid as much as 500 atmospheres were necessary.

TABLE 12.—*Compressibility of para-toluidine,* $C_7H_7NH_2$. *Boiling point, 198°; melting point, 43°.*

θ, L	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed. $\frac{v}{V} \times 10^3$	Diff. $\times 10^1$	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$
*28° 14·14cm	20	0·0	0·0	.....	0.0	±0·0	.....	.....
	100	4·3	4·6	56	4·6	—0·1	59	60
	200	10·0	10·0	56	10·2	—0·2	.....	.....
	300	15·8	15·6	56	15·5	+0·2	.....	.....
	400	20·6	20·9	55	20·5	+0·2	.....	.....
65° 14·73cm	20	0·0	0·0	.....	0·0	±0·0	.....	.....
	100	5·5	5·5	69	5·3	+0·2	68	69
	200	11·6	11·9	65	11·7	±0·0	.....	.....
	300	17·4	17·4	62	17·7	—0·3	.....	.....
	400	23·5	23·5	62	23·4	+0·1	.....	.....
100° 15·02cm	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	6·3	6·3	79	6·8	—0·5	87	88
	200	14·5	14·5	81	14·7	—0·2	.....	.....
	300	22·2	22·3	79	21·1	+0·1	.....	.....
	400	29·0	29·3	77	28·8	+0·4	.....	.....
185° 16·36cm	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	11·0	10·9	137	10·6	+0.4	138	142
	200	22·8	22·8	127	22·5	+0·3	.....	.....
	300	33·4	33.4	119	33·1	+0·3	.....	.....
	400	42·4	42·2	112	43·1	—0·8	.....	.....
310° 19·05cm	20	0·0	0·0	.....	.....	0·0	392	422
	100	29·0	29·4	365	27·6	+2·0	.....	.....
	200	56·1	52·0	300	54·5	+2·0	.....	.....
	300	76·2	75·7	271	76·3	—0·0	.....	.....
	400	92·7	92·5	243	94.5	—0·2	.....	.....

* Liquid, undercooled. Solidifies under 500 atmospheres.

Digitized by Google

TABLE 13.—*Thermal expansion of para-toluidine,* $\frac{v}{V} \times 10^3$, *referred to 28°.*

Atm. =		20	100	200	300	400
θ =	28	0	0	0	0	0
	65	42	41	40	39	38
	100	63	60	57	56	53
	185	158	149	142	136	131
	310	348	313	287	265	247

20. *Diphenylamine.*—In the value for diphenylamine, given in Tables 14 and 15, the initial pressure is unfortunately zero. This introduces a discrepancy between the present and the other results, in which the initial pressure is significant. The observations are not as uniform as the above. Cf. Pl. VII. It may be noted that at 2,000 atmospheres, supposing the given conditions of Pl. VII, Fig. 2, to last, no contraction would occur on cooling.

TABLE 14.—*Compressibility of diphenylamine. Melting point, 54°; boiling point, 310°.*

L, θ	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed. $\frac{v}{V} \times 10^3$	Diff. $\times 10^3$	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$
16·2cm 65°	0	0·0	0·0	.....	0·0	—0·0	.....	.....
	100	6·5	6·0	63	6·3	—0·0	65	65
	200	11·9	11·9	60	12·2	—0·2	.....	.....
	300	17·9	17·3	59	17·9	—0·3	.....	.....
	400	23·2	22·5	57	23·5	—0·7	.....	.....
	500	29·2	28·4	57	28·4	+0·9	.....	.....
16·4cm 100°	0	0·0	0·0	.....	0·0	0·0	.....	.....
	100	6·1	6·3	62	6·7	—0·5	69	69
	200	12·8	13·1	64	13·1	—0·2	.....	.....
	300	19·3	19·3	64	19·0	+0·3	.....	.....
	400	24·6	25·1	63	24·7	+0·1	.....	.....
	500	29·9	30·5	60	30·1	+0·1	.....	.....
17·7cm 185°	0	0·0	0·0	.....	0·0	+0·0	110	110
	100	11·2	10·7	110	10·4	+0·6	.....	.....
	200	20·6	20·3	102	20·0	+0·5	.....	.....
	300	29·2	28·9	97	28·9	—0·1	.....	.....
	400	37·1	36·1	91	37·0	—0·4	.....	.....
	500	44·1	44·3	89	44·7	—0·5	.....	.....
19·7cm (20·3)cm 310°	0	0·0	0·0	.....	0·0	0·0	.....	.....
	100	18·5	17·8	202	19·4	—1·2	213	213
	200	36·1	36·1	190	36·0	+0·1	.....	.....
	300	51·5	50·7	176	50·3	+0·7	.....	.....
	400	62·4	63·5	161	63·1	—0·1	.....	.....
	500	74·1	75·1	152	74·6	0·0	.....	.....

TABLE 15.—*Thermal expansion of diphenylamine,* $10^3 \times \frac{v}{V}$, *referred to 66°.*

Atm. =		0	100	200	300	400	500
θ =	65°	0·0	0·0	0·0	0·0	0·0	0·0
	100°	12·4	12·4	11·3	10·1	10·1	11·0
	185°	93·0	88·0	83·1	80·0	78·0	76·0
	310°	235·0	221·0	205·0	193·0	186·0	178·0

Digitized by Google

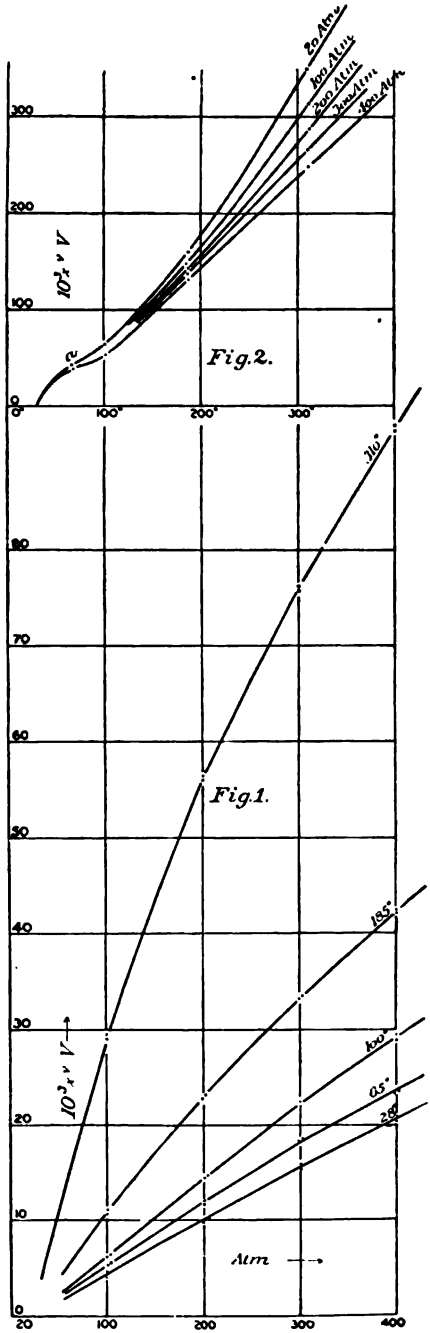


FIG. 1. Relative isothermals of toluidine. p_0=20 atmospheres, θ_0=28°.
FIG. 2. Relative isopiestics of toluidine. p_0=20 atmospheres, θ_0=28°.

Digitized by Google

Digitized by Google

21. *Caprinic acid.*—Tables 16 and 17, and Plate VIII, contain the results for caprinic acid. The thermal expansion is irregular, probably due to motion of the thread in the tube, so that virtually two different threads were observed. The substance has a low melting point, 30°. Undercooled to 25° I found that it solidified at 300 atmospheres pressure.

TABLE 16.—*Compressibility of caprinic acid,* $C_{10}H_{20}O_2$. *Melting point, 30°; boiling point, 269°.*

θ, L	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed. $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
30° (Undercooled.) 15·91cm	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	4·9	5·7	66	5·9	—0·6	76	76
	200	13·4	12·9	73	12·9	+0·3	.....	.....
	300	19·5	19·8	71	19·5	+0·2	.....	.....
	400	25·5	25·8	68	25·7	0·0	.....	.....
65° 14·39cm	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	7·3	7·0	90	7·3	—0·1	95	97
	200	16·1	15·9	89	16·0	0·0	.....	.....
	300	23·6	23·9	84	23·8	0·0	.....	.....
	400	31·4	31·1	82	31·3	0·0	.....	.....
100° 16·85cm	20	0·0	0·0	.....	0·0	0·0	119	121
	100	8·5	9·1	110	9·0	—0·2	.....	.....
	200	19·1	20·1	109	19·5	+0·1	.....	.....
	300	29·1	28·9	104	29·1	—0·1	.....	.....
	400	36·8	36·8	97	37·8	+0·2	.....	.....
185° 18·30cm	20	0·0	0·0	.....	0·0	0·0	200	207
	100	15·3	15·1	190	14·9	+0·3	.....	.....
	200	31·2	31·1	173	31·2	0·0	.....	.....
	300	45·4	45·5	163	45·2	+0·3	.....	.....
	400	57·4	57·1	151	57·7	—0·4	.....	.....

TABLE 17.—*Thermal expansion of caprinic acid,* $\frac{v}{V}\times 10^3$, *referred to 30°.*

Atm.=		20	100	200	300	400
θ=	30°	0	0	0	0	0
	65°	30	28	28	26	25
	100°	59	55	52	49	47
	185°	151	139	129	120	113

22. *Benzoic acid.*—In view of the high melting point only a single series of measurements was made. Table 18 contains the results.

TABLE 18.—*Compressibility of benzoic acid,* $C_7H_6O_2$. *Melting point, 121°; boiling point, 249°.*

L, θ	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed. $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
185° 11·88cm	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	11·4	11·4	142	10·5	+0·9	138	141
	200	22·3	22·1	124	22·3	—0·1	.....	.....
	300	32·8	33·1	118	33·2	—0·2	.....	.....
	400	42·1	42·5	112	42·9	—0·6	.....	.....

Digitized by Google

23. *Paraffin.*—I made many measurements with paraffin, of which the following digest, Tables 19 and 20, probably contains the best results. At 64° solidification set in at 400 atmospheres. This is well seen in Pl. IX. Supposing the conditions to hold indefinitely, there would be no contraction on cooling under a pressure of 1,200 atmospheres.

TABLE 19.—*Compressibility of paraffin. Melting point, 50°.*

L, θ	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed. $\frac{v}{V} \times 10^3$	Diff. $\times 10^3$	$\vartheta \times 10^6$	$\delta_\theta \times 10^6$
64° 15·86cm	20	0·0	0·0	.....	0·0	−0·0	.....	.....
	100	6·8	6·5	83	6·8	−0·1	88	89
	200	14·9	14·9	83	14·8	+0·1	.....	.....
	300	23·6	23·8	84	.....	.....	.....	.....
	400	(*)	(56·6)	(149)	.....	.....	.....	.....
100° 16·28cm	20	0·0	0·0	.....	0·0	−0·0	.....	.....
	100	8·5	8·5	106	8·5	0·0	111	114
	200	18·5	18·7	103	18·5	+0·1	.....	.....
	300	27·6	27·7	99	27·4	+0·2	.....	.....
	400	35·6	35·8	94	35·8	−0·1	.....	.....
185° 17·57cm	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	13·8	13·8	172	13·3	+0·5	178	184
	200	27·9	28·2	156	28·1	0·0	.....	.....
	300	41·2	41·4	147	41·1	+0·2	.....	.....
	400	52·3	52·0	137	52·7	−0·5	.....	.....
310° 19·70cm	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	26·8	26·2	331	26·0	+0·5	366	392
	200	51·9	52·1	289	51·7	+0·3	.....	.....
	300	72·4	71·8	257	72·7	−0·6	.....	.....
	400	89·9	89·6	236	90·3	−0·6	.....	.....

* Solidifying.

TABLE 20.—*Thermal expansion of paraffin,* $\frac{v}{V} \times 10^3$, *referred to 64°.*

Atm. =	20	100	200	300	400
θ = 64	0·0	0·0	0·0	0·0	0·0
100	26·4	24·1	23·1	22·6	22·1
185	108·0	100·0	92·9	87·8	83·8
310	241·0	210·0	196·5	181·0	167·0

24. Further results for paraffin are given in Table 21 and the chart, Pl. X. In this case the capillary tube was closed above by fusion, and the parffian introduced in vacuo. Solidification takes place at 65° under 500 atmospheres. The divers columns v/V were obtained in separate ments on different days.

Digitized by Google

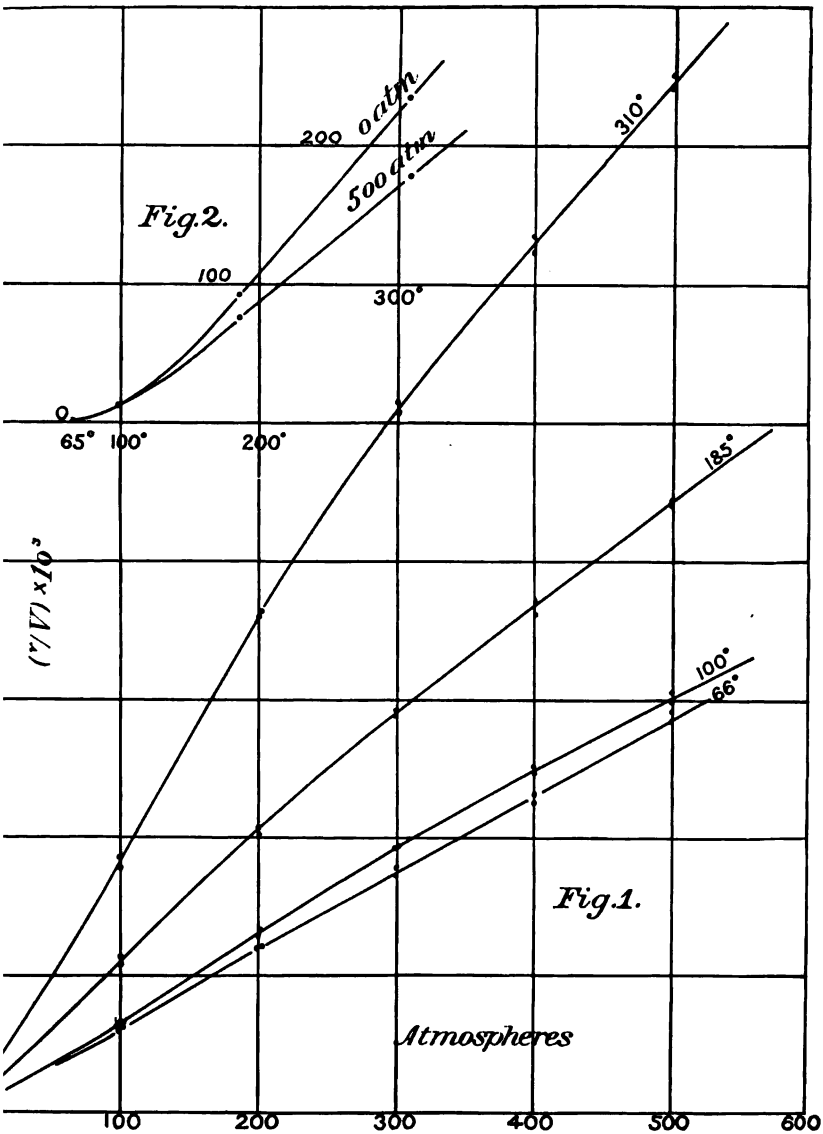


FIG. 1. Relative isothermals of diphenylamine. $p_0=0$, $\theta_0=66°$.
FIG. 2. Relative isopiestics of diphenylamine. $p_0=0$, $\theta_0=66°$.

Digitized by Google

Digitized by Google

TABLE 21.—*Compressibility of paraffin. Melting point, 55°.*

θ, L	p	$\frac{v}{V}\times 10^3$	$\frac{v}{V}\times 10^3$	$\frac{v}{V}\times 10^3$	$\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed. $\frac{v}{V}\times 10^3$	$\vartheta_0\times 10^6$
185° 18·9cm	0	0·0	0·0	0·0	0·0	.....	0·0	.....
	100	17·6	17·8	17·1	18·1	176	17·2	186
	200	31·8	32·2	32·2	32·4	161	31·9	.....
	300	45·0	45·3	45·8	45·7	151	45·2	.....
	400	56·1	55·9	56·4	56·9	141	56·8	.....
	500	.....	.....	67·1	(*)	134	67·4	.....
100° 17·6cm	0	0·0	0·0	0·0	0·0	.....	0·0	.....
	100	11·4	11·4	11·4	11·4	114	11·2	118
	200	22·0	21·8	21·7	21·5	109	21·4	.....
	300	31·6	31·0	30·6	30·6	102	30·7	.....
	400	39·2	39·2	39·4	38·9	98	39·3	.....
	500	.....	.....	46·9	46·9	94	47·2	.....
65° 17·0cm	0	0·0	0·0	0·0	0·0	.....	0·0	.....
	100	10·3	9·9	10·0	9·8	100	9·5	100
	200	18·6	18·1	18·4	18·4	92	18·4	.....
	300	26·3	26·2	.....	.....	87	26·6	.....
	400	†34·6	34·3	.....	.....	86	.....	.....
	500	80·0	.....	.....	.....	(160)	.....	.....

* Tube breaks. † Solidifying, solid at 500 atmospheres.

25. *Thymol.*—Tables 22 and 23 and the accompanying Pl. XI, give ull account of the behavior of thymol. Like toluidine, § 19, thymol adiits of considerable undercooling, and the isopiestic increments show rcumflexure in this region. (See Fig. 2, at *a*.) Supposing all conitions to hold, no volume change would ensue on cooling under 1,200 mospheres pressure.

ABLE 22.—*Compressibility of thymol,* $C_{10}H_{14}O$. *Melting point, 53°; boiling point, 233°.*

θ, L	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed. $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
* 28° 14·67cm	20	0·0	0·0	.....	0·0	.....	.....	.....
	100	5·5	5·3	67	5·1	+0·3	65	66
	200	10·9	11·0	61	11·1	—0·1	.....	.....
	300	17·0	17·0	61	16·7	+0·3	.....	.....
	400	21·8	21·7	57	22·1	—0·4	.....	.....
64° 15·29cm	20	0·0	0·0	.....	0·0	.....	.....	.....
	100	5·6	5·4	69	5·7	—0·2	74	75
	200	12·4	12·3	69	12·6	—0·2	.....	.....
	300	19·6	19·9	70	19·0	+0·7	.....	.....
	400	25·5	24·5	66	25·1	—0·1	.....	.....
100° 15·78cm	20	0·0	0·0	.....	0·0	.....	.....	.....
	100	7·6	7·5	94	7·4	+0·1	96	97
	200	16·2	16·2	90	16·0	+0·2	.....	.....
	300	24·4	24·2	86	23·9	+0·4	.....	.....
	400	30·7	30·9	80	31·4	—0·6	.....	.....

* Liquid undercooled.

Digitized by Google

TABLE 22.—*Compressibility of thymol*, $C_{10}H_{14}O$—Continued.

θ, L	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed. $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
185° 17·05^{cm}	20	0·0	0·0	.....	0·0	.....	.....	.....
	100	12·3	12·2	153	12·2	0·0	161	166
	200	26·1	25·9	144	25·8	+0·2	.....	.....
	300	38·0	37·8	135	37·8	+0·1	.....	.....
	400	48·3	48·5	127	48·8	−0·4	.....	.....
310° 19·5^{cm}	20	0·0	0·0	.....	0·0	.....	.....	.....
	100	33·0	32·0	407	31	+0·2	448	487
	200	61·1	60·5	338	61	+0·1	.....	.....
	400	83·6	83·6	299	84	−0·1	.....	.....
	300	102·0	101·0	267	103	−0·2	.....	.....

ANOTHER SAMPLE.

310° 16·47^{cm}	20	0·0	.....	.....	.....	.....	.....	.....
	100	34·0	.....	425	.....	.....	.....	.....
	200	62·4	.....	347	.....	.....	.....	.....
	300	82·5	.....	295	.....	.....	.....	.....
	400	102·0	.....	269	.....	.....	.....	.....

TABLE 23.—*Thermal expansion of thymol*, $\frac{v}{V}\times 10^3$, *referred to 28°*.

Atm. =		20	100	200	300	400
θ =	28°	.....	.....	.....	.....	.....
	65°	42	43	41	39	39
	100°	76	73	71	68	65
	185°	162	154	145	138	130
	310°	329	293	263	239	220

26. In §§ 26 to 29 results are given for a variety of substances. In view of the high melting points, only two series for each were feasible. At 310° azobenzol decomposes. The results were rejected. The use of this colored substance pointed out an irremediable error, due to the adhesion of a film of substance to the glass, between the mercury and the walls of the tube. In case of compression, the advancing thread of mercury therefore moves on a cushion, as it were.

TABLE 24.—*Compressibility of monobrom camphor*, $C_{10}H_{15}BrO$. *Melting point, 76°; boiling point, 274°.*

θ, L	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed. $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
100° 14·03^{cm}	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	6·6	6·6	82	6·6	0·0	83	85
	200	14·1	14·1	78	14·3	−0·2	.....	.....
	300	21·5	21·5	77	21·4	+0·1	.....	.....
185° 14·80^{cm}	20	0·0	0·0	.....	0·0	0·0	.....	.....
	100	9·8	9·9	123	9·5	+0·4	123	126
	200	20·0	19·9	111	20·2	−0·2	.....	.....
	300	29·7	29·9	106	30·1	−0·3	.....	.....

Digitized by Google

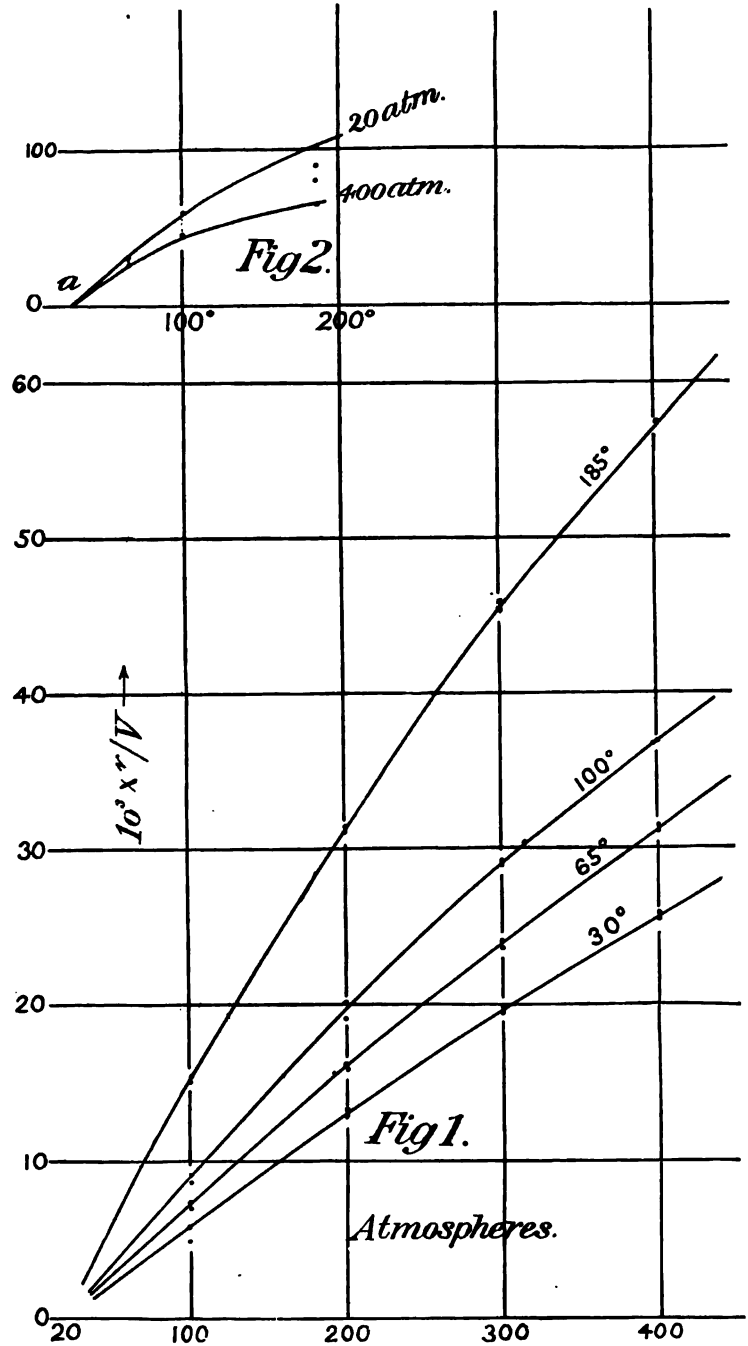


FIG. 1. Relative isothermals of caprinic acid. p_0=20 atmospheres, θ_0=30°.
FIG. 2. Relative isopiestics of caprinic acid. p_0=20 atmospheres, θ_0=30°.

Digitized by Google

Digitized by Google

TABLE 25.—*Thermal expansion of monobrom camphor,* $\frac{v}{V} \times 10^3$, *referred to 100°.*

Atm. =		20	100	200	300
θ =	100°				
	185°	0·55	0·51	0·49	0·46

TABLE 26.—*Compressibility of α-naphthol,* $C_{10}H_8O$. *Melting point, 94°; boiling point, 279°.*

θ, L	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed. $\frac{v}{V} \times 10^3$	Diff. $\times 10^3$	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$
100° 15·10^{cm}	20	0·0	0·0		0·0	0·0		
	100	5·6	6·0	72	4·9	+0·9	62	62
	200	10·3	10·7	58	10·6	—0·1		
	300	15·9	16·1	57	16·1	—0·1		
	400	20·5	20·5	54	21·3	—0·8		
185° 15·97^{cm}	20	0·0	0·0		0·0	0·0		
	100	6·7	6·8	85	6·6	+0·2	85	87
	200	14·3	14·4	80	14·4	0·0		
	300	21·3	21·6	77	21·6	—0·1		
	400	28·6	28·4	75	28·4	+0·1		

TABLE 27.—*Thermal expansion of α-naphthol,* $\frac{v}{V} \times 10^3$, *referred to 100°.*

Atm. =		20	100	200	300	400
θ =	100°	0	0	0	0	0
	185°	58	57	54	51	49

TABLE 28.—*Compressibility of azobenzol,* $C_{12}H_{10}N_2$. *Boiling point, 293°; melting point, 66°.*

θ, L	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\frac{v}{V} \times \frac{1}{p}$	Computed. $\frac{v}{V} \times 10^3$	Diff. $\times 10^3$	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$
100° 16·29^{cm}	20	0·0	0·0		0·0	0·0		
	100	6·5	6·3	80	6·2	+0·2	79	80
	200	13·2	13·3	74	13·3	0·0		
	300	20·3	20·4	72	20·1	+0·3		
	400	26·4	26·2	69	26·6	—0·3		
185° 17·49^{cm}	20	0·0	0·0		0·0	0·0		
	100	10·1	9·8	125	10·0	0·0	131	134
	200	21·2	21·3	118	21·3	0·0		
	300	31·6	31·6	113	31·4	—0·2		
	400	41·1	40·9	108	40·9	—0·1		

Digitized by Google

TABLE 29.—*Expansion of azobenzol,* $\frac{v}{V} \times 10^3$, *referred to 100°.*

Atm.=		20	100	200	300	400
θ=	100°	0	0	0	0	0
	185°	74	71	66	64	61

29. TABLE 30.—*Compressibility of vanilline,* $C_8H_8O_3$. *Melting point, 80°; boiling point, 285°.*

θ, L	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed.	Diff. $\times 10^3$	$\phi \times 10^6$	$\phi_0 \times 10^6$
100°	20	0·0	0.0	.....	0·0	0·0	.....	.....
15·04^{cm}	100	4·1	3·9	50	4·6	—0·6	58	58
	200	9·5	9·6	53	9·9	—0·3	.....	.....
	300	16·1	15·6	57	15·0	+0·9	.....	.....
185°	20	0·0	0·0	.....	0·0	0·0	.....	.....
16·10^{cm}	100	7·1	7·2	90	7·1	+0·1	92	93
	200	15·5	15·9	87	15·4	+0·3	.....	.....
	300	22·7	22·7	81	23·1	—0·4	.....	.....

TABLE 31.—*Expansion of vanilline,* $\frac{v}{V} \times 10^3$, *referred to 100°.*

Atm.=		20	100	200	300
θ=	100°	0	0	0	0
	185°	71	67	65	64

30. *Naphthalene.*—The results of the following two tables were obtained without an upper mercury thread, and are therefore affected by the error discussed in § 15. They contain many points of special interest, however, and, in view of the long threads ($L = 20^{cm}$), I think the discrepancy in question slight. It will be seen that at 100° naphthalin solidifies at 600 atmospheres. Monochlor-acetic acid did not solidify outright. The compressibility observed for the solid column I believe to be due to the presence of an excess of water of crystallization in the hygroscopic acid. Compressibility here is a *solution phenomenon*, and the excessively large value of β is thus explicable. The same phenomenon will be observed below, Chapter III, in case of silicated water.

A few other substances (phenanthrene, sodic acetate) were tried, but without obtaining publishable results.

Digitized by Google

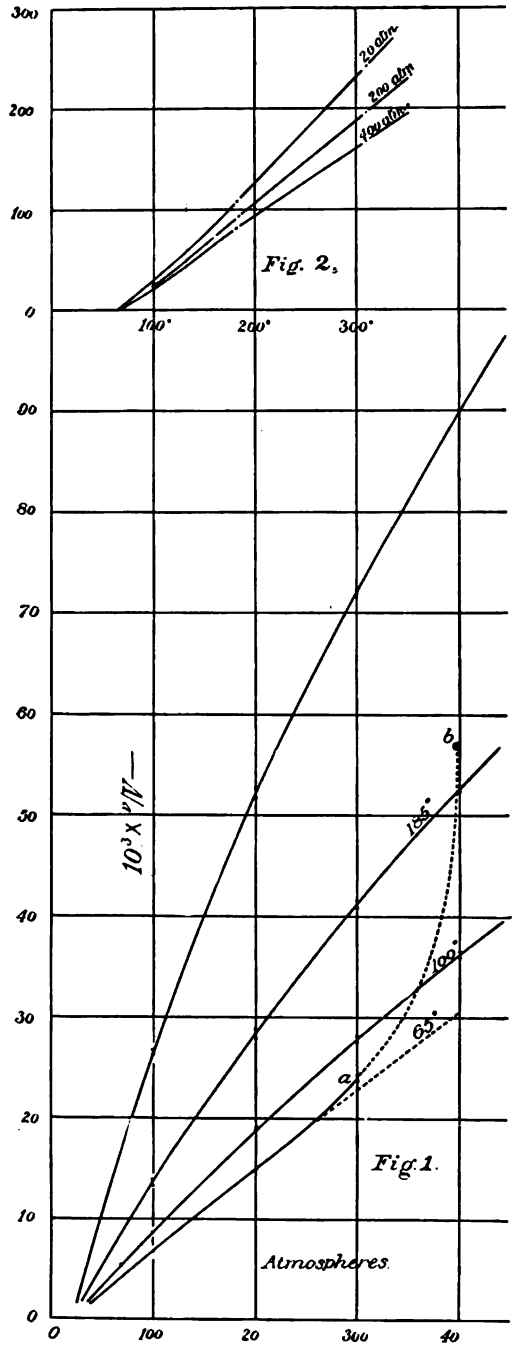


FIG. 1. Relative isothermals of paraffin. $p_0=20$ atmospheres, $\theta_0=65°$.
FIG. 2. Relative isopiestic of paraffin. $p_0=20$ atmospheres, $\theta_0=65°$.

Digitized by Google

Digitized by Google

TABLE 32.—*Compressibility of naphthalene. Melting point, 80°; boiling point, 215°.*

L, θ	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed. $\frac{v}{V} \times 10^3$	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$
21·2cm 185°	50	0·0	0·0	.....	0·0	133	141
	150	13·2	12·5	129	12·5	.....	.....
	250	24·3	24·3	122	23·8	.....	.....
	350	33·7	33·7	112	34·0	.....	.....
	450	43·2	42·4	106	43·4	.....	.....
20·8cm 153°	50	0·0	.....	.....	0·0	115	121
	150	11·1	.....	111	10·9	.....	.....
	250	21·4	.....	107	20·8	.....	.....
	350	30·1	.....	101	29·9	.....	.....
	450	37·8	.....	94	38·4	.....	.....
21·7cm 100°	50	0·0	0·0	.....	0·0	93	97
	150	8·5	8·3	84	8·9	.....	.....
	250	17·3	16·8	85	17·2	.....	.....
	350	25·1	24·6	83	24·9	.....	.....
	450	32·3	32·3	81	31·9	.....	.....
	550	.....	39·1	78	38·8	.....	.....
21·7cm 100°	50	0·0	.....	.....	.....	.....	.....
	300	20·7	.....	83	.....	.....	.....
	400	29·5	.....	84	.....	.....	.....
	500	36·9	.....	82	.....	.....	.....
	*600	52·5	.....	96	.....	.....	.....

* Solid.

31. TABLE 33.—*Compressibility of monochlor-acetic acid. Melting point, 62°; boiling point, 188°.*

θ, L	p	Observed. $\frac{v}{V} \times 10^3$	Observed. $\frac{v}{V} \times 10^3$	$\beta \times 10^6$	Computed. $\frac{v}{V} \times 10^3$	$\vartheta_0 \times 10^6$
185° 22·2cm	50	0·0	.....	.....	0·0	142
	150	14·9	.....	149	13·3	.....
	250	25·2	.....	126	25·2	.....
	350	36·0	.....	120	36·0	.....
	450	44·6	.....	112	45·7	.....
65° 20·3cm	50	0·0	0·0	.....	0·0	72
	150	7·4	7·4	74	6·9	.....
	250	13·8	13·8	69	13·6	.....
	350	20·3	20·0	68	19·8	.....
	450	25·7	25·2	64	25·7	.....
	550	30·7	.....	61	31·2	.....
*56° 17·8cm	50	0·0	.....	.....	.....	.....
	150	10·0	.....	100	.....	.....
	250	17·0	.....	85	.....	.....
	350	21·4	.....	71	.....	.....
	450	24·2	.....	61	.....	.....

* Column solid.

Digitized by Google

METHOD OF DISCUSSION.

32. *Plan pursued.*—I shall endeavor to discuss the above data in the following way: Having given certain relations between volume and pressure obtaining at any given temperature, let a close-fitting function be investigated, such that for the same pressures the calculated values of volume decrement must eventually be *greater* than the observed values will be. Let another function be investigated, such that for the same pressures the calculated values of volume decrement must eventually be less than the observed values can be. The actual data must therefore lie within the band or pathway included between the two functions in question. In other words, the couple of functions maps out an isothermal zone, as it were.

Now, suppose it is possible (the proof will be given by trial) to so adjust the two functions that throughout the interval of observation they both fall within the limits of error, then it is probable that any property which is simultaneously predicted by both functions may confidently be assumed as the property of the unknown isothermal. So long, therefore, as the two functions do not diverge seriously, there is here given a judicious method of extrapolation, by which relations beyond the limits of experiment may be apprehended.

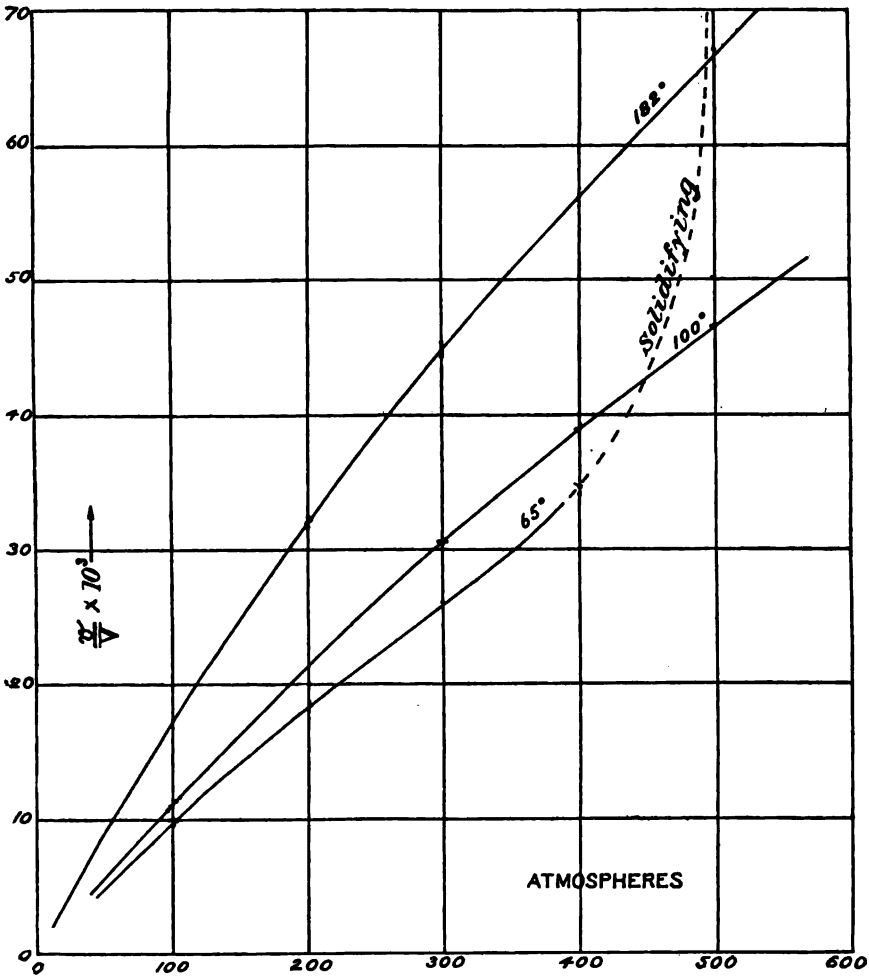
33. *Quadratic constants.*—Now, in order to arrive at the probable nature of such functions, it is expedient to pass parabolas through the observations. The ordinary vertical parabola is clearly inapplicable. It predicts a maximum, and is therefore incompatible with the nature of the locus to be found. Nevertheless, the zero compressibility may thus be deduced with some certainty, and, moreover, from the relation of the two constants, additional inferences may be gleaned.

In Table 34 I have entered the two constants in question, respectively denoted by m and n, supposing that

$$y_\theta = 10^3 v/V = mp - np^2,$$

where y_θ is the volume decrement at the pressure p, under conditions of constant temperature θ. The table further contains boiling and melting points (B. P. and M. P., respectively), as well as the total thermal expansion E, from $\theta = 0°$ to the value of θ cited, when $p = 0$.

Digitized by Google



Relative isothermals of paraffin. $p_0=0$, $\theta_0=65$.

Digitized by Google

Digitized by Google

TABLE 34.—*Quadratic constants which reproduce the isothermal decrements.*

ubstance.	θ	$10^8 \times m$.	$10^6 \times n$.	$10^1 \times E$.
aitic acid: B. P., 350° M. P., 62°	310°	315	267	199
	185°	161	93	107
	100°	100	36	26
	65°	88	25	0
-toluidine: B. P., 198° M. P., 43°	310°	387	404	348
	185°	141	81	158
	100°	81	6	63
	65°	69	25	42
	28°	56	3	0
enylamine: B. P., 310° M. P., 54°	310°	197	92	235
	185°	113	54	93
	100°	64	3	12
	65°	62	12	0
inic acid: B. P., 270° M. P., 30°	185°	196	125	151
	100°	116	46	59
	65°	92	27	30
	30°	71	5	0
ic acid: B. P., 249° M. P., 121°	185°	143	93	.....
ine: M. P., 55°	310°	349	320	210
	185°	177	110	100
	100°	110	43	24
	65°	83	9	0
ol: B. P., 233° M. P., 53°	310°	435	484	329
	185°	159	85	102
	100°	97	40	76
	65°	69	2	42
	28°	67	26	0

Substance.	θ	$10^8 \times m$.	$10^6 \times n$.	$10^3 \times E$.
Monobrom camphor: B. P., 274° M. P., 76°	185°	129	80	55
	100°	85	28	0
α Naphthol: B. P., 280° M. P., 94°	185°	85	29	58
	100°	70	50	0
Azobenzol: B. P., 293° M. P., 68°	185°	127	52	74
	100°	86	29	0
Vanilline: B. P., 285° M. P., 80°	185°	92	39	71
	100°	47	32	0
Alcohol: B. P., 78°	310°	3,280	6,970	1,290
	185°	341	418	229
	100°	178	209	87
	65°	111	28	35
	28°	87	20	0
Ether: B. P., 34°	310°	3,583	6,367	1,770
	185°	776	992	397
	100°	340	346	131
	65°	224	170	57
	29°	167	107	0

RESSIBILITY INCREASING INVERSELY AS THE PRESSURE BINOMIAL.

Transition to exponential constants.—There are two points of view which the data of Table 34 are important:

Compressibility m increases at a rapidly accelerated rate with temre, caet. par. (2) Compressibility m and the datum for curvature intimately related. This points out that a fundamental relation and p will probably exist independently of the material operated

§ 13. The quantity E serves for orientations only, since it is not icient.

s necessary to look at these points more in detail. In case of l and ether at 310°, quadratic constants are impossible: for the ium would either lie within the field of observation, or the obsers would have to be grossly slighted. This is to some extent true er at 185°. The alcohol and ether data in Table 34 are therefore d merely for comparison.

cting these exceptional cases, it appears, if the dependence of n e considered separately for each substance as well as collectively

Digitized by Google

for all, that the quantities vary nearly linearly with each other. Suppose $2n = b(m - a)$.

To return to the above equation,

$$y = mp - np^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\text{or } dy/dp = m\left(1 - \frac{2n}{m}p\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

replace m by ϑ and $2n/m$ by α, for the sake of distinction. Then inasmuch as (1) applies more accurately in proportion as p is small, equation 2 may be put

$$dy/dp = \vartheta/\overline{1 + \alpha p} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

whence

$$y = ln(1 + \alpha p)^{\vartheta/\alpha} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This equation has an advantage over the equation (1): it does not predict a maximum. It is, therefore, compatible with the character of the isothermals in the above tables. Furthermore, in view of its simplicity, and of the fact that generally $y = \infty$ when $p = \infty$, it may be taken as the lower limit of the isothermal ribband described in § 32. For it is clear that when $p = \infty$, v/V can not be greater than unity.

In passing I may insert a few remarks on the relation of constants. Since $\vartheta = m$ and $2n/m = \alpha$, it follows that $\alpha = b(m - a)/m$ and $\vartheta/\alpha = m^2/b(m - a.)$ Hence approximate values for the constants in (4) may be derived from Table 34. From an inspection of this table I was moreover led to infer that at the melting point, compressibility is constant and independent of pressure. In other words, since $1/\vartheta = 1/a - \alpha/ab$, $\vartheta = a$ would be the criterion of fusion. Subsequent results did not substantiate this surmise, § 38. Another similar notion that the resistance to compression is equal to the incipient resistance to extension even in liquids, and that therefore $1/\vartheta$ must have a constant value at the boiling point independent of substance, is not warranted by the experiments made. Such a relation was suggested by the experiments of Kahlbaum[1] corroborated by O. Schumann,[2] according to which the boiling point corresponding to a given pressure is higher than the temperature of the same vapor tension. Ramsay and Young,[3] who tested these experiments, do not corroborate them. They effectually substantiate Regnault's law according to which vapor tensions, whether obtained by the static or the dynamic method, are identical.

35. *Properties of the exponential equation.*—It will facilitate discussion if certain salient properties of equation (4) are grouped together here. I may state that, *a priori*, the occurrence of $y = 10^3 v/V = \infty$ for $p = \infty$, is not a fatal objection to its application; for the use of the

[1] Kahlbaum: Chem. Ber., vol. 18, 1885, p. 3146. O. Schumann: Chem. Ber., vol. 18, 1885, p 2085.

[2] Ramsay and Young: Chem. Ber., vol. 18, 1885, p. 2855; vol. 19, 1886, p. 69.

Digitized by Google

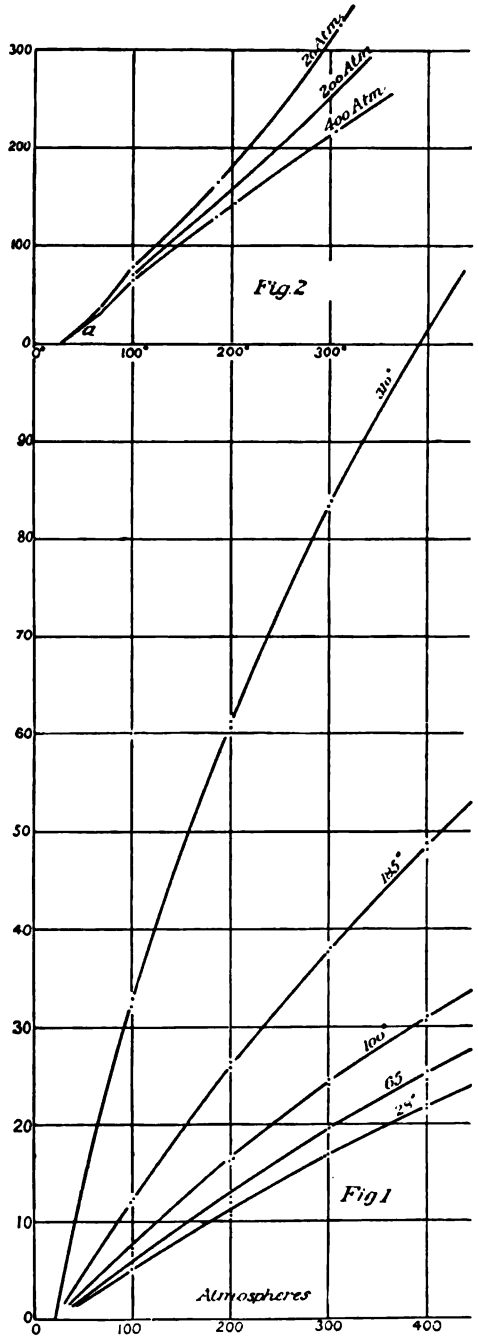


FIG. 1. Relative isothermals of thymol. p_0=30 atmospheres, θ_0=28°.
FIG. 2. Relative isopiestics of thymol. p_0=20 atmospheres, θ_0=28°.

Digitized by Google

Digitized by Google

ition ceases at the point of solidification by pressure; therefore, at
a finite value of p, as far as which the equation $y = ln(1+\alpha p)^{\vartheta/\alpha}$
faithfully represent the volume changes (decrements) observed.
this reason I originally accepted this equation with the assurance
s possessing a value beyond that of defining an arbitrary limit of
sothermal band.
ppose for a given substance

$$y' = ln\Big(1+\alpha_0(p_0+p)\Big)^{\vartheta_0/\alpha_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

simultaneously,

$$y_0 = ln(1+\alpha_0 p_0)^{\vartheta_0/\alpha_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

e p_0 and p are any two consecutive intervals of pressure. Then

$$y = y' - y_0 = ln\left(\frac{1+\alpha_0(p_0+p)}{1+\alpha_0 p_0}\right)^{\vartheta_0/\alpha_0} = ln\left(1+\frac{\alpha_0}{1+\alpha_0 p_0}p\right)^{\vartheta_0/\alpha_0} \quad . \quad (7)$$

e if

$$\alpha = \frac{\alpha_0}{1+\alpha_0 p_0} \quad \text{and} \quad \vartheta = \frac{\vartheta_0}{1+\alpha_0 p_0} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

ion (7) may be put

$$y = ln(1+\alpha p)^{\vartheta/\alpha} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

from the observations y, made along any arc of the whole curve,
en p_0 and p, it is at once possible to obtain the constants of the
curve referred to the origin at 0 atmosphere, by equations (8) or
uivalent equations:

$$\alpha_0 = \frac{\alpha}{1-\alpha p_0} \quad \text{and} \quad \vartheta_0 = \frac{\vartheta}{1-\alpha p_0} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

t the reductions are simple. Equations (9) suggest an important
uence: when $\alpha p_0 > 1$, both α_0 and ϑ_0 become imaginary. Now it
atter for curious remark that this takes place in case of ether
cohol near or above the critical temperature. Hence I inferred
he compressibility of liquids $d\frac{v}{V}/dp = -\vartheta/(1+\alpha p)$ changes
nd passes into the compressibility of gases

$$\frac{d\frac{v}{V}}{dp} = -\frac{1}{p}$$

h an imaginary expression.
ich a consideration the condition for critical temperature would
$1/\alpha$.

Digitized by Google

When p is small, equation (4) becomes

$$y = \vartheta p - \tfrac{1}{2}\alpha\vartheta p^2 + \ldots\ldots,$$

which is shown to be capable of further simplification in the next section.

The expression for compressibility

$$d\left(\frac{v}{V}\right)/dp = \vartheta/(1+\alpha p)$$

has a counterpart which is applicable for thermal expansion, viz,

$$d\left(\frac{v}{V}\right)/d\theta = \tau/(1-\beta\theta),$$

as will be shown in § 41.

Finally, the change of p, when regarded as the function of the radius ρ of any unit sphere within the compressed liquid, is of interest. Let p be expressed by $f(\rho)$, where ρ in the uncompressed liquid is unity. Then

$$1-\rho^3 = ln(1+\alpha f(\rho))^{\vartheta/\alpha}$$

$$f(\rho) = \frac{1}{\alpha}\left(e^{\alpha(1-\rho^3)/\vartheta} - 1\right)$$

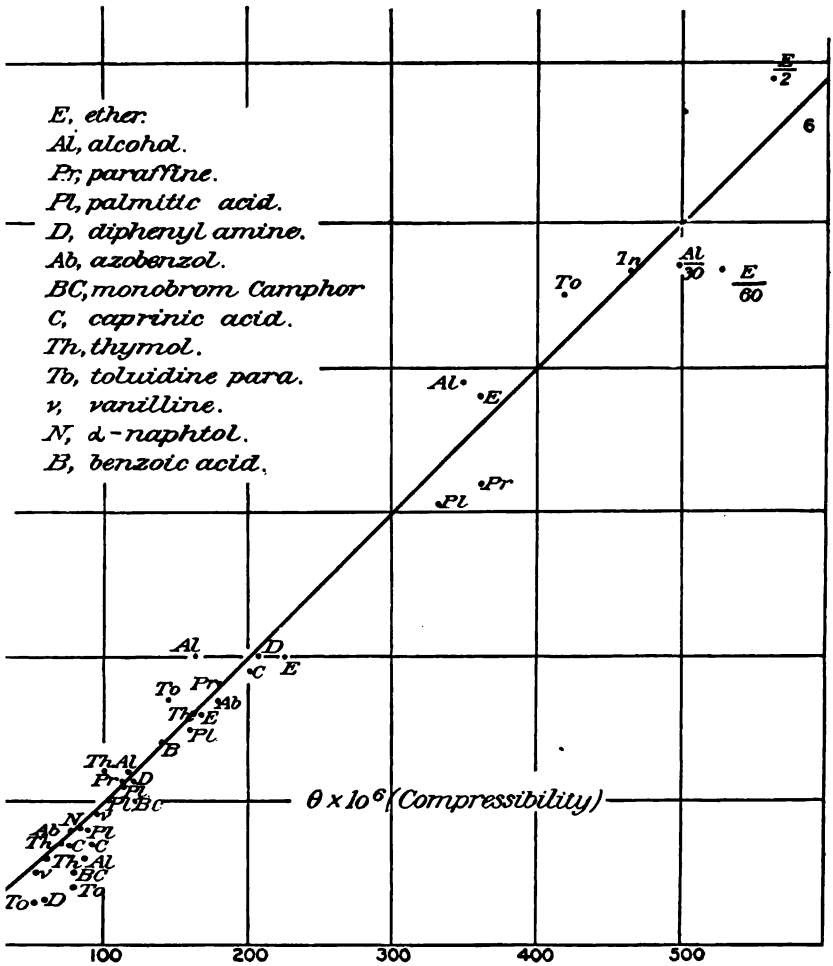
This equation shows the nature of the inadequacy of (4); for if ρ decrease indefinitely, $f(\rho)$ eventually becomes $\frac{1}{\alpha}\left(e^{\alpha/\vartheta} - 1\right)$. In the next paragraph α/ϑ is found to be nearly 9. Hence the limit in question is $8290/\alpha$. In the cases where equation (4) applies this value is somewhere between 10^6 and 10^7 atmospheres. Hence the interval within which equation (4) may apply satisfactorily is reasonably large.

36. *Exponential constants computed.*—After the suggestion contained in § 34 approximate values for the exponential constants in the equation $v/V = ln(1+\alpha p)^{\vartheta\ \alpha}$ are easily derived.[1] The constants thus obtained are very crude, and the calculated results show a wide margin of error. Hence, starting with these, I computed the accurate values by a method of gradual approximation, finally selecting such values of ϑ and α as reduced the errors to a reasonably small limit. This computation is exceedingly tedious and unsatisfactory at best, because pairs of values of ϑ and α, differing very widely from each other, are often found to satisfy the equation about equally well. Nevertheless, it was necessary to avoid any scheme of selection other than the criterion of errors specified, the object being to obtain a set of constants independent of any ulterior purposes or considerations.

The results are given in Table 35, in which the first column contains the boiling point (B. P.), melting point (M. P.), of the divers substances

[1] Reference to y is conveniently dropped here. The constants refer to $\frac{v}{V}$.

Digitized by Google



Relation of pressure coefficient and compressibility.

Digitized by Google

Digitized by Google

ell as the initial pressure P_0, for which ϑ, the zero compressibility, α, the pressure coefficient, apply at the temperature θ. From these ss to ϑ_0 and α_0, which hold for the initial pressure 0 atmosphere, by itions 9, § 35. The table also contains the reciprocal of compressi- y $1/\vartheta$, or the resistance to compression which obtains under each ie given conditions. Finally, the value of ϑ_0/α_0, with a coefficient by aid of which the computation is reduced from naperian to com- logarithms, is inserted in the last column. At the end of the table ve added the mean datum ϑ_0/α_0, derived from all the values of the , with its probable error. A chart (Pl. XII) accompanies the table.

E 35.—*Exponential constants which reproduce the isothermal decrements—Direct computations.*

ubstance.	θ	$\vartheta \times 10^6$	$\alpha \times 10^3$	$1/\vartheta$	$\vartheta_0 \times 10^6$	$\alpha_0 \times 10^3$	$1/\vartheta_0$	$2{\cdot}3\frac{\vartheta_0}{\alpha_0} \times 10^3$
tic acid:	310°	332	3·05	3,010	353	3·25	2,830	250
P., 350°	185°	160	1·50	6,250	165	1·55	6,060	245
. P., 62°	100°	104	1·00	9,610	106	1·02	9,030	238
) — 20	65°	89	0·80	11,240	90	0·81	11,060	257
oluidine:	310°	421	4·50	2,370	463	4·95	2,160	215
P., 198°	185°	145	1·70	6,900	150	1·76	6,670	196
. P., 43°	100°	82	0·40	12,200	89	0·43	11,240	473
= 20	65°	68	0·50	14,600	76	0·56	13,250	315
	28°	57	0·30	173,900	61	0·32	16,530	441
ylamine:	310°	216	2·00	4,630	216	2·00	4,630	248
P., 310°	185°	113	1·20	8,850	113	1·20	8,850	217
P., 54°	100°	68	0·50	14,710	68	0·50	14,710	311
= 0	65°	62	0·30	16,130	62	0·30	16,130	474
ic acid:	185°	201	1·90	4,970	209	1·98	4,780	243
P., 270°	100°	114	1·00	8,770	116	1·02	8,620	263
P., 30°	65°	92	0·70	10,870	93	0·71	10,750	303
= 20	30°	77	0·70	13,000	78	0·71	12,820	252
acid:								
., 249°	185°	140	1·40	7,140	144	1·44	6,940	230
P., 121°								
= 20								
:	310°	362	3·20	2,760	387	3·42	2,580	260
., 55°	185°	180	1·80	5,560	187	1·87	5,350	231
= 20	100°	113	1·120	8,850	116	1·15	8,620	232
	65°	89	0·80	11,240	91	0·81	11,050	256
:	310°	466	4·66	2,150	514	5·14	1,950	230
., 233°	185°	163	1·60	6,135	168	1·65	5,950	234
., 53°	100°	100	1·20	10,000	103	1·22	9,710	191
20	65°	74	0·70	13,510	75	0·71	13,300	243
	28°	65	0·60	15,380	66	0·61	15,150	248
m cam-								
. 274°	185°	121	1·00	8,260	124	1·02	8,060	270
.. 76°	100°	82	0·50	12,200	83	0·51	12,050	376
20								
ol:	185°	86	0·80	12,500	87	0·81	11,490	246
. 280°	100°	63	0·70	14,290	64	0·71	15,630	207
.. 94°								
20								

Digitized by Google

TABLE 35.—*Exponential constants, etc.*—Continued.

Substance.	θ	$\vartheta \times 10^6$	$\alpha \times 10^4$	$1/\vartheta$	$\vartheta_0 \times 10^6$	$\alpha_0 \times 10^4$	$1/\vartheta_0$	$2{\cdot}3\frac{\vartheta_0}{\alpha_0} \times 10^3$
Vanilline:								
B. P., 285°.....	185°	96	0·90	10,420	98	0·92	10,200	235
M. P., 80°.....	100°	59	0·50	16,950	60	0·51	16,700	271
P_0=20.....								
Azobenzol:								
B. P., 293°.....	185°	130	1·20	7,690	133	1·23	7,520	250
M. P., 68°.....	100°	80	0·80	12,500	81	0·81	12,350	229
P_0=20.....								
Alcohol:	310°	15,000	140·00	67	(*)	(*)	(*)	247
	185°	351	3·90	2,850	836	9·29	1,200	207
B. P., 78°.....	100°	164	2·00	6,100	234	2·86	4,270	189
P_0=150.....	65°	116	1·20	8,620	142	1·46	7,040	223
	30°	88	0·60	11,360	97	0·66	10,310	336
Ether:	310°	31,800	280·0	314	(*)	(*)	(*)	261
	185°	1,130	12·0	885	(*)	(*)	(*)	217
B. P..35°.....	100°	361	3·8	2,770	583	6·13	1,720	218
P_0=100.....	65°	225	2·0	4,440	281	2·50	3,560	259
	30°	167	1·6	5,990	199	1·91	5,020	240

* Equation fails, indicating transition into gaseous state.

$$\text{Mean } 2{\cdot}3\frac{\vartheta_0}{\alpha_0} = {\cdot}2575 \pm {}^{00}83 \qquad \frac{\vartheta_0}{\alpha_0} = {\cdot}1119 = \frac{1}{9} \text{ (say).}$$

37. *Mean exponential constants derived.*—The tabulated constants for ether and alcohol above 185° substantiates the remarks made in § 35 relative to the limit of application if the equation $v/V = ln\,(1+\alpha p)^{\vartheta/\alpha}$. The critical temperatures of these substances[1] are 195° and 234°, respectively. Hence ether shows an imaginary ϑ_0 as low as 185°, and both substances do so at 310°.

The point of special interest relative to this table follows from a consideration of the last column $2{\cdot}3\vartheta_0/\alpha_0$. In Fig. 21, where these results are given graphically (ϑ as abscissa, α as ordinate), their signification fully appears. To obtain a figure of reasonable dimensions for ether and alcohol, I have divided large pairs of ϑ and α, each by the same convenient number, as is indicated in the figure. This does not change their ratio. Looking at these results as a whole, and taking the enormous range of variation fully into consideration, it appears beyond question that ϑ and α are not only closely related, but that this relation is probably linear. The computation of Table 35 was an entirely independent procedure, and I could easily have obtained data more nearly in keeping with the mean ratio ϑ/α had I entered upon the work with any bias.

Hence I am justified in considering the equation given at the end of Table 35,

$$v/V = ln\,(1+9\vartheta p)^{1/9}$$

as applicable to the whole series of organic substances examined. With

[1] Ramsey: Proc. Roy. Soc., London, vol. 31, 1880, p. 194; Hannay, ibid, vol. 30, 1880, p. 484; and others. Cf. Landolt and Boernstein's tables, l. c.

Digitized by Google

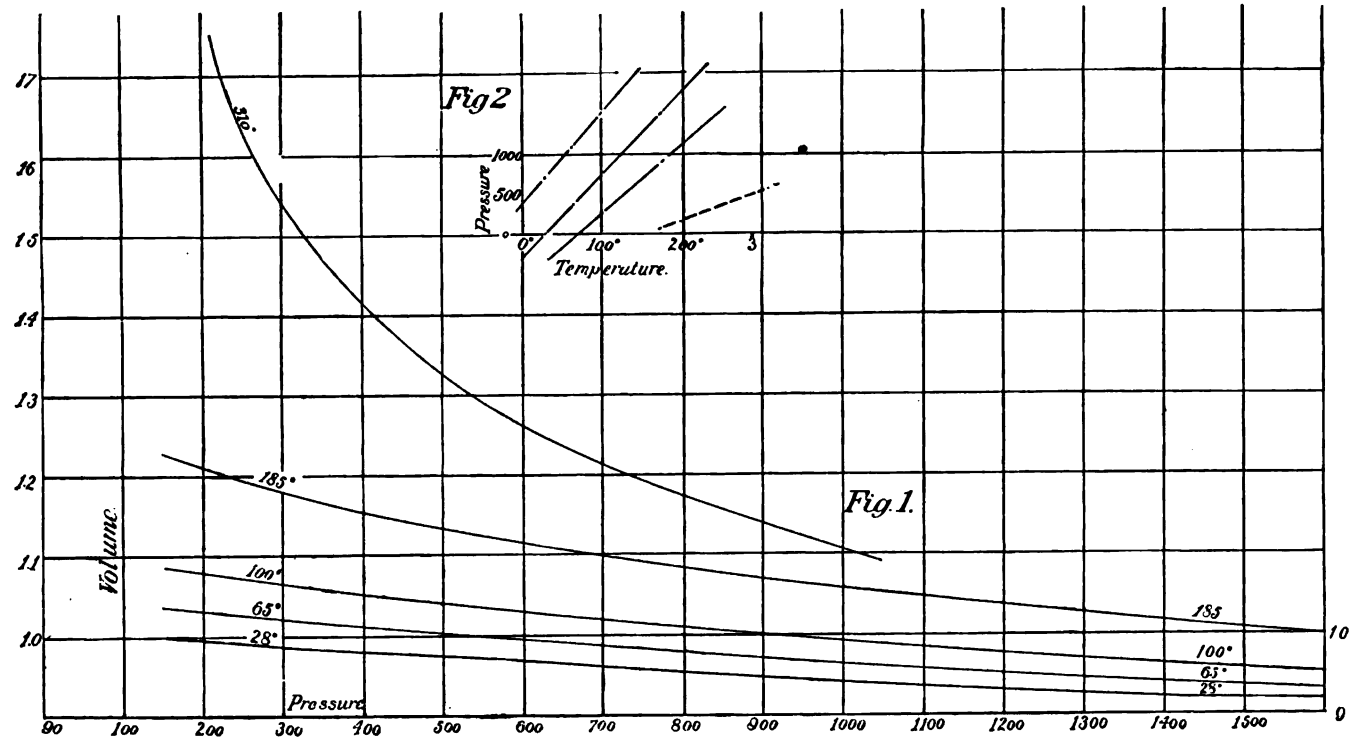


FIG. 1. Isothermals of alcohol.
FIG. 2. Isometrics of alcohol.

Digitized by Google

Digitized by Google

as a point of departure, I made a recalculation of ϑ and have in-ed the results in Table 36. Naphthalin and monochlor acetic acid added.

TABLE 36.—*Mean exponential constants* $v/V = ln\,(1+\vartheta\vartheta p)$ *i.*

ibstance.	θ	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$	$1/\vartheta_0$
r:	29°	105	194	6,061
= 100 atm..	65°	226	282	4,425
P. = 34° ...	100°	343	497	2,915
	185°	1,005	10,060	995
	310°	34,250	(*)	292
ol:	28°	89	101	11,240
= 150 atm..	65°	115	136	8,700
P. = 78° ...	100°	158	201	6,330
	185°	331	598	3,020
	310°	13,830	(*)	722
tic acid:	65°	91	93	10,750
= 20	100°	102	104	9,610
. P. = 62° ...	185°	160	165	6,060
P. = 350° ..	310°	330	351	285
oluidine:	28°	59	60	16,670
= 20°	65°	68	69	14,490
. P. = 43° ..	100°	87	88	11,360
P. = 198° ..	185°	138	142	7,040
	310°	392	422	2,370
ylamine:	65°	65	65	15,380
= 0	100°	69	69	14,490
P. = 54° ...	185°	110	110	9,090
P. = 310° ..	310°	213	213	4,690
ic acid:	30°	76	76	13,160
= 20	65°	95	97	10,310
P. = 30° ...	100°	119	121	8,260
P. = 270° ..	185°	200	207	4,830
acid:				
= 20				
P. = 121° .	185°	138	141	7,090
P. = 249° ..				
:	64°	88	†89	11,240
20	100°	111	114	8,770
. = 55° ...	185°	178	184	5,430
	310°	366	392	2,550

Substance.	θ	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$	$1/\vartheta_0$
Paraffin, other samples: $p_0 = 0$	65°		†100	10,000
	100°		118	8,470
	185°		186	5,380
Thymol: $p_0 = 20$ ..... M. P. = 51° .. B. P. = 233° ..	28°	65	66	15,150
	64°	74	75	13,330
	100°	96	97	10,310
	185°	161	166	6,020
	310°	448	487	2,050
Monobrom camphor: $p_0 = 20$ ..... M. P. = 76° .. B. P. = 274° ..	100°	83	85	11,760
	185°	123	126	7,940
α-Naphthol: $p_0 = 20$ ..... M. P. = 94° ... B. P. = 280° ..	100°	62	62	16,130
	185°	85	87	11,490
Azobenzol: $p_0 = 20$ ..... M. P. = 68° ... B. P. = 293° ..	100°	79	80	12,500
	185°	131	134	7,460
Vanillin: $p_0 = 20$ ..... M. P. = 83° ... B. P. = 285° ..	100°	58	58	17,210
	185°	92	93	10,750
β-Naphthalin: $p_0 = 50$ ..... M. P. = 80° ... B. P. = 215° ..	100°	93	97	10,310
	153°	115	121	8,260
	185°	133	141	7,090
†Monochlor acetic acid: $p_0 = 0$ ..... M. P. = 62° ... B. P. = 188° ..	65°		72	13,890
	185°		142	7,040

ılts of an older method. In ether and alcohol the reciprocals of ϑ are taken instead of $1/\vartheta_0$.
repancy in these results due to solidification.
ginar..

iling myself of these constants, I computed the values of v/V n Tables 4 to 33. By consulting the differences between observed lculated, it will be seen that the errors are as a rule within the of accuracy specified in the critical paragraphs 9 to 15.

Subsidiary results.—Certain subsidiary results of Table 36 are to tioned. If $1/\vartheta$, the resistance to compression, be constructed as ion of temperature, θ, it will be seen that, except in the extreme f alcohol and ether, $1/\vartheta$ decreases nearly proportional to θ. This decrease is nearly the same for all substances examined.

able 37 I have given the approximate values of ϑ at melting

Digitized by Google

points, M. P., and at boiling points, B. P. No perspicuous relation is discernible, thus substantiating the inferences already drawn in § 34. It appears that compressibility is a quantity depending on other causes than the stability of molecular groups.

TABLE 37.—*Compressibility at melting and at boiling points.*

Substance.	M. P.	$\vartheta_0 \times 10^6$	B. P.	$\vartheta_\theta \times 10^6$
Palmitic acid	62°	90	350°	(290)
Toluidine	43	62	198	160
Diphenylamine	54	60	310	213
Caprinic acid	30	76	270	.....
Paraffin	55	83	.....	.....
Thymol	53	70	233	240
Brom. camphor	76	76	274	.....
α-Naphtol	94	60	280	.....
Vanilline	80	55	285	.....
Azobenzol	68	65	293	.....
Naphthalene	80	90	215	(170)
Chlor acetic acid	62	72	188	145
Alcohol (ϑ_{150})	.....	.....	78	130
Ether (ϑ_{100})	.....	.....	34	170

39. *Isothermals computed.*—With these results in hand I am able to reach the chief issue of the present paper, viz., the construction of the actual isothermals for the substances in hand. The computation being somewhat laborious, it will scarcely be fruitful to consider those substances in which the heat expansion could not be accurately measured. § 14. The data to be discussed are notably alcohol, ether, paraffin, thymol, para-toluidine, and diphenylamine.

To recapitulate: The volume decrement,

$$v/V = ln\,(1+9\vartheta p)^{1/9} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

refers in all cases to unit of volume at the temperature θ of the isothermal and under the initial pressure P_0. The compressed volume is therefore.

$$1 - ln\,(1+9\vartheta p)^{1/9}$$

and if in consequence of the *observed* thermal expansion at P_0, the volume at θ be V_ϑ the actual isothermal is obviously

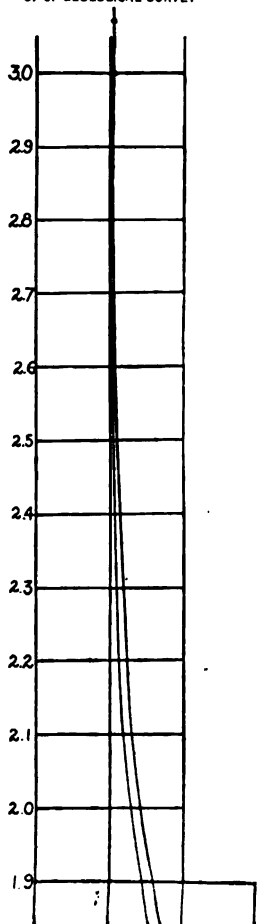
$$v_{\theta p} = v_\theta(1 - ln\,(1+9\vartheta p)^{1/9}) \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

referred to the initial temperature θ_0. It is to be observed that v_ϑ is directly measured, and that, therefore, the only hypothesis occurring in equation (11) is equation (10).

In Tables 38 to 43, I have given $v_{\theta p}$ computed conformably with equations (11) for pressure as high as 1,500 atmospheres and for the temperatures of observation. A chart accompanies each table, in which pressures, p, are given as abscissæ volumes $v_{\theta p}$ as ordinates. From these charts, Plates XIII to XVIII, the conditions subject to which temperature and pressure must vary in order that $v_{\theta p}$ may remain constant are at once given by drawing horizontals. Hence, to each of the Tables 38 to 43 I have a supplement, in which values of θ and p for

Digitized by Google

Digitized by Google



Digitized by Google

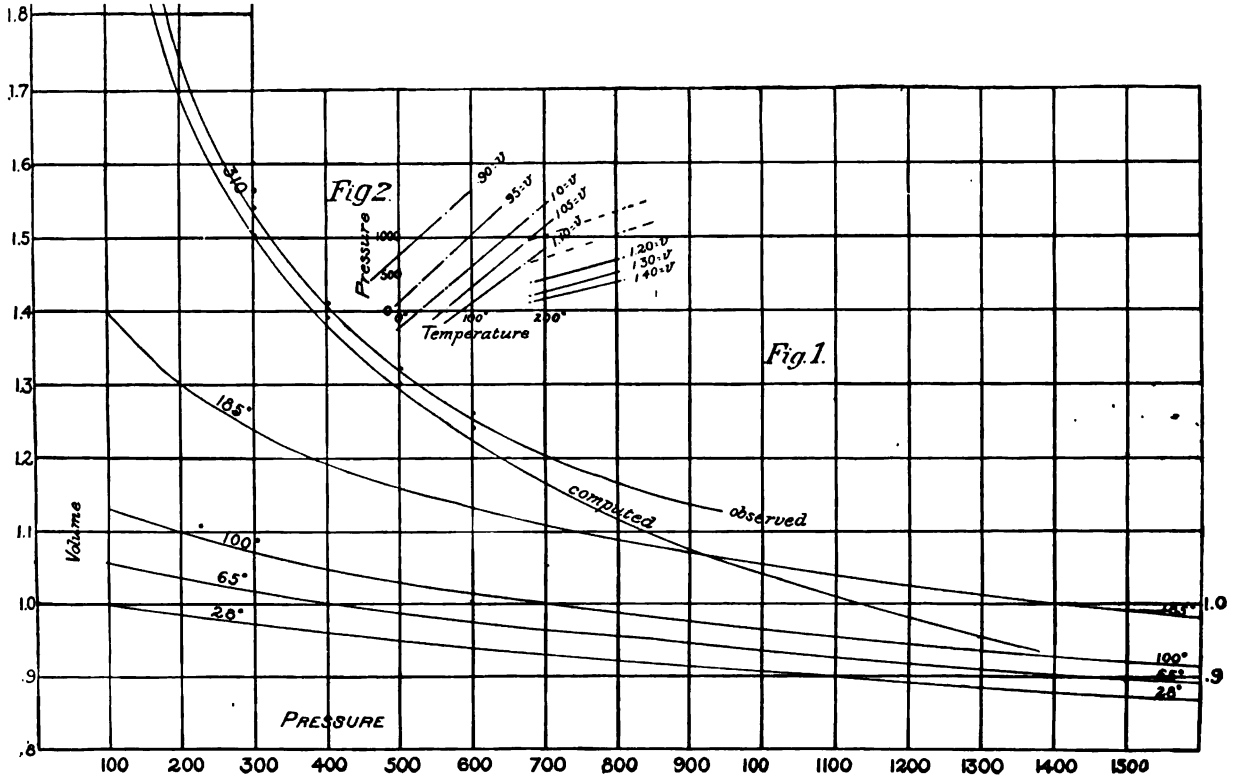


FIG. 1. Isothermals of ether.
FIG. 2. Isopiestics of ether.

Digitized by Google

Digitized by Google

$v_{\theta p}$ = const. are inscribed. These supplementary tables indicate the nature of the isometrics. $V_{\mu\theta}$ will be computed in the next section.

TABLE 38.—*Isothermals of ether, referred to unit of volume at 28° and 100 atmospheres.*

p	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.
	*310°		185°		100°		65°		28°	
0										
100	(†)	2·77	(†)	1·397	1·131	1·131	1·057	1·057	1·000	1·000
200	.....	1·70	.....	1·298	1·096	1·097	1·035	1·035	0·984	0·984
300	.....	1·50	.....	1·236	1·070	1·071	1·017	1·017	0·971	0·971
400	.....	1·38	.....	1·193	1·050	1·049	1·002	1·001	0·959	0·959
500	.....	1·29	.....	1·159	1·033	1·030	0·988	0·987	0·949	0·948
600	.....	1·22	.....	1·132	1·020	1·014	0·977	0·974	0·939	0·938
700	.....	1·16	.....	1·109	1·008	1·000	0·967	0·963	0·931	0·929
800	.....	1·12	.....	1·088	0·999	0·986	0·958	0·953	0·923	0·921
900	.....	1·08	.....	1·069	0·991	0·975	0·951	0·944	0·917	0·913
1,000	.....	1·04	.....	1·053	0·983	0·964	0·944	0·935	0·910	0·906
1,100	.....	1·01	.....	1·039	0·976	0·955	0·937	0·927	0·905	0·899
1,400	.....	0·93	.....	1·001	0·962	0·929	0·922	0·904	0·890	0·881
1,600	.....	0·88	.....	0·983	0·955	0·914	0·914	0·893	0·882	0·870

* Special measurement made later. † Equation fails.

Critical conditions of constant volume.

θ	Δp.	Volume.
28	0	1·00
65	310	.....
100	600	.....
185	1,300	.....

Rate = 0·12° per atmosphere.

TABLE 39.—*Isothermals of alcohol, referred to unit of volume at 28° and 150 atmospheres.*

p	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.
	310°		185°		100°		65°		28°	
0										
150	(†)	2·29	1·229	1·229	1·087	1·087	1·035	1·035	1·000	1·000
250	.....	1·63	1·193	1·193	1·070	1·071	1·024	1·024	0·991	0·991
350	.....	1·47	1·165	1·165	1·056	1·057	1·013	1·014	0·983	0·983
450	.....	1·37	1·143	1·142	1·043	1·044	1·004	1·004	0·975	0·976
550	.....	1·29	1·125	1·122	1·032	1·033	0·995	0·996	0·968	0·969
650	.....	1·24	1·111	1·105	1·022	1·022	0·987	0·988	0·962	0·963
750	.....	1·19	1·098	1·089	1·013	1·013	0·980	0·980	0·956	0·956
850	.....	1·16	1·088	1·075	1·005	1·004	0·974	0·973	0·951	0·951
950	.....	1·12	1·079	1·063	0·998	0·995	0·968	0·966	0·945	0·945
1,050	.....	1·09	1·071	1·051	0·991	0·988	0·962	0·960	0·940	0·940
1,150	.....	1·06	1·064	1·041	0·985	0·980	0·956	0·954	0·935	0·935
1,450	.....	1·00	1·047	1·013	0·969	0·961	0·942	0·938	0·923	0·921
1,650	.....	0·96	1·038	0·997	0·960	0·949	0·934	0·928	0·916	0·912

Critical conditions of constant volume.

θ	Δp.	Volume.
28	0	1·0
65	360	.....
100	740	.....
185	1,470	.....

Rate = 0·12° per atmosphere.

Digitized by Google

TABLE 40.—*Isothermals of paraffin, referred to unit volume at 65° and 20 atmospheres.*

p	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.
	310°		185°		100°		65°	
20	1·241	1·241	1 108	1·108	1·026	1·026	1·000	1·000
120	1.201	1·202	1·090	1·090	1·015	1·015	0·991	0·991
220	1·171	1·171	1·074	1·074	1·005	1·005	0·983	0·983
320	1·147	1·146	1·060	1·060	0·996	0·996	0·975	0·975
420	1·129	1·125	1·045	1·047	0·988	0·988	0·969	0·968
520	1·113	1·107	1·037	1·036	0·980	0·980	0·962	0·962
620	1·101	1·091	1·027	1·025	0·973	0·973	0·955	0·956
720	1·091	1·076	1·018	1·016	0·967	0·966	0·951	0·950
820	1·081	1·063	1·011	1·007	0·960	0·959	0·946	0·945
920	1·074	1·051	1·003	0·999	0·955	0·953	0·941	0·939
1,020	1·067	1·040	0·997	0·991	0·949	0·947	0·936	0·935
1,320	1·051	1·012	0·982	0·970	0·935	0·931	0·924	0·921
1,520	1·043	0·995	0·973	0·958	0·928	0·922	0·916	0·912

Critical conditions of constant volume.

θ	Δp.	Volume.
65	0	1·00
100	250	.....
185	880	.....
310	1. 430	.....

Rate = 0·13° per atmosphere.

TABLE 41.—*Isothermals of diphenylamine, referred to unit volume at 65° and 0 atmospheres.*

p	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.
	310°		185°		100°		65°	
0	1·235	1·235	1·093	1·093	1·012	1·012	1·000	1·000
100	1·211	1·211	1·081	1·082	1·005	1·006	0·994	0·994
200	1·191	1·191	1·071	1·071	0·999	0·999	0·987	0·988
300	1·173	1·173	1·061	1·061	0·993	0 993	0·981	0·982
400	1·159	1·157	1·052	1·053	0·987	0·988	0·976	0·977
500	1·146	1·143	1·044	1·044	0·982	0 982	0·971	0·971
600	1·134	1·130	1·034	1·036	0·977	0·976	0·966	0·967
700	1·124	1·119	1·030	1·029	0·970	0·972	0·962	0·962
800	1·116	1·108	1·023	1·022	0·967	0·967	0 957	0·957
900	1·107	1·098	1·017	1 016	0·963	0·962	0 954	0·953
1,000	1·100	1·089	1·012	1·010	0·959	0·958	0·950	0·949
1,300	1·082	1·064	0·997	0 993	0·948	0·945	0·938	0·937
1,500	1·073	1·050	0·989	0·983	0·941	0·938	0·932	0·930

Critical conditions of constant volume.

θ	Δp.	Volume.
65	0	1·00
100	190	.....
185	1, 200	.....

Rate = 0·09° per atmosphere.

Digitized by Google

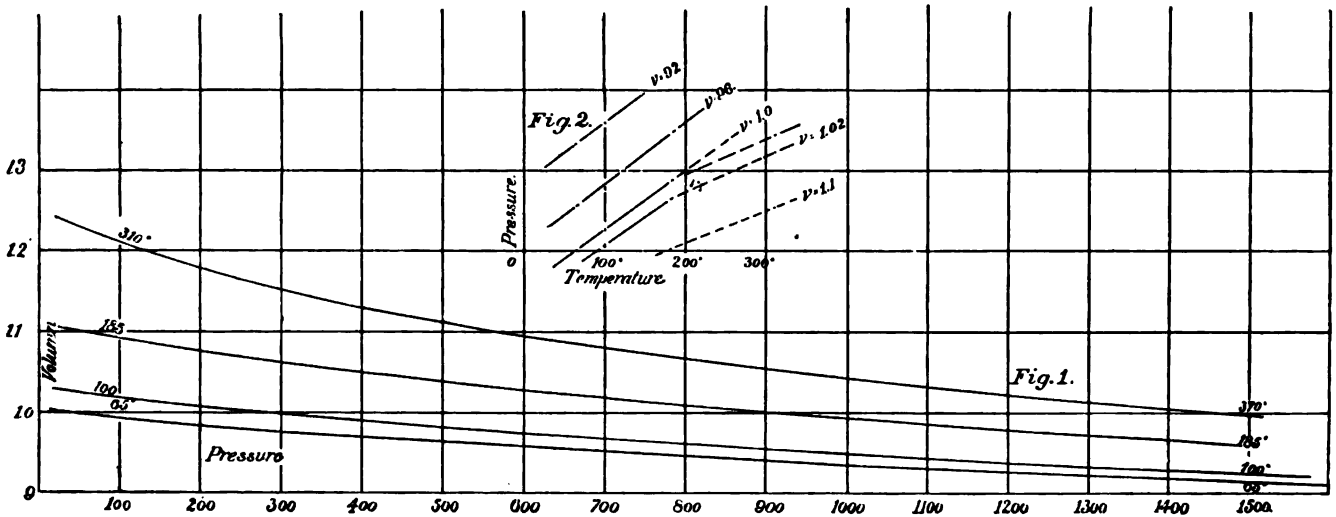


FIG. 1. Isothermals of paraffin.
FIG. 2. Isometrics of paraffin.

Digitized by Google

Digitized by Google

TABLE 42.—*Isothermals of paratoluidine, referred to unit volume at 28° and 20 atmospheres.*

p	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.
	310°		185°		100°		65°		28°	
20	1·348	1·348	1·158	1·158	1·063	1·063	1·042	1·042	1·000	1·000
120	1·301	1·303	1·143	1·143	1·054	1·054	1·035	1·035	0·996	0·994
220	1·267	1·268	1·129	1·130	1·046	1·046	1·029	1·028	0·989	0·989
320	1·241	1·240	1·117	1·117	1·039	1·038	1·022	1·022	0 983	0 983
420	1·220	1·216	1·106	1·106	1·031	1·030	1·016	1·017	0·978	0·978
520	1·204	1·196	1·096	1·096	1·025	1·023	1·011	1·011	0 973	0·973
620	1·190	1·178	1·087	1·087	1·019	1·017	1·006	1·006	0·968	0·969
720	1·179	1·162	1·079	1·078	1·013	1·011	1·001	1·001	0·964	0·965
820	1·169	1·147	1·071	1·069	1·007	1·005	0·996	0·996	0 960	0·960
920	1·160	1·134	1·065	1·062	1·002	1·000	0·992	0 992	0·954	0·956
1,020	1·154	1·122	1·058	1·055	0·997	0·994	0·987	0 987	0 952	0·952
1,320	1·136	1·090	1·042	1·035	0·984	0·979	0·976	0·974	0·942	0·941
1,520	1·127	1·072	1·032	1·023	0·977	0·970	0·969	0·967	0·936	0·934

Critical conditions of constant volume.

θ	Δp.	Volume.
28	(−650)	.....
65	25	1·04
100	270	.....
185	1,200	.....
310	(1,850)	.....

Rate = 0·10° per atmosphere.

TABLE 43.—*Isothermals of thymol, referred to unit volume at 28° and 20 atmospheres.*

p	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.	$V_{\mu\theta}$.	$V_{\partial\theta}$.
	*310°		185°		100°		65°		28°	
20	1·329	1·329	1·162	1·162	1·076	1·076	1·042	1·042	1·000	1·000
120	1·277	1·279	1·145	1·145	1·066	1·066	1·035	1·035	0 994	0·994
220	1·240	1·242	1·129	1·129	1·057	1·057	1·028	1·028	0·987	0·988
320	1·212	1·212	1·116	1·116	1·048	1·049	1·021	1·021	0·981	0·982
420	1·192	1·188	1·104	1·103	1·040	1·041	1·015	1·015	0 976	0·977
520	1·175	1·167	1·093	1·092	1·033	1·033	1·010	1·009	0·971	0·972
620	1·162	1·148	1·084	1·081	1·026	1·026	1·004	1·003	0·965	0·967
720	1·151	1·131	1·075	1·072	1·020	1·020	0·999	0·998	0·961	0·962
820	1·142	1·116	1·067	1·064	1·014	1·013	0·994	0·993	0 956	0·957
920	1·134	1·103	1·060	1·055	1·008	1·007	0·989	0·988	0·952	0·953
1,020	1·127	1·091	1·053	1·047	1·003	1·002	0·985	0·983	0·948	0·949
1,320	1·111	1·059	1·037	1·026	0·989	0·986	0·973	0·970	0 937	0·937
1,520	1·103	1·040	1·027	1·014	0·981	0·977	0·966	0·961	0·931	0·930

* Special experiment, made later.

Critical conditions of constant volume.

θ	Δp.	Volume.
28	(−620)	.....
65	40	1·04
100	410	.....
185	1,090	.....
310	1,500	.....

Rate = 0·10° per atmosphere.

Digitized by Google

40. *Isometrics.*—From the importance of the subject it is necessary nt peruse the Tables 38 to 43 somewhat more in detail than was done io earlier work. In case of alcohol (Table 39) the curves for 28° to 185°, Pl. XIII, are a family of like properties; the curve for 310°, however, intersects these in the region of high pressures (1,500 atmospheres). Here, therefore, is additional corroboration of the remarks made in § 35, that above the critical temperature equation (10) is not applicable. The case may be more serious. It is also supposable that the 310° is only an accentuated expression of the shortcomings of equation (4) in general. I call to mind that this equation has only been used as the upper numerical limit of the isothermal band, for volume decrements: hence a lower limit for volumes. See next section.

The chief result of the present table is given by the supplementas tables: for $V_{\theta p} = V_{28,150} = 1$, θ and p as far as 185° are linear functionl of each other. This is well shown in Pl. XIII, Fig. 2, and Pl. XIX below. The rate of change is one-tenth degree C. per atmosphere.

Results of the same kind hold for ether, Table 38, Pl. XIV, although the high temperature discrepancy conformably with the lower critical temperature is somewhat more pronounced. The rate of variation of θ and p for $V_{\theta p} = V_{28,100} = 1$ is here 0·12° C. per atmosphere. This also is clearly shown in Pl. XIII.

In case of paraffin, Table 40, which is the first substance solid at ordinary temperatures $V_{\theta p} = V_{65,120} = 1$ also shows a somewhat larger variation of θ and p, the rate being 0·13° C. per atmosphere. A notable peculiarity of these curves is the occurrence of a discrepancy at 310° similar to that of ether and alcohol, but much less pronounced.

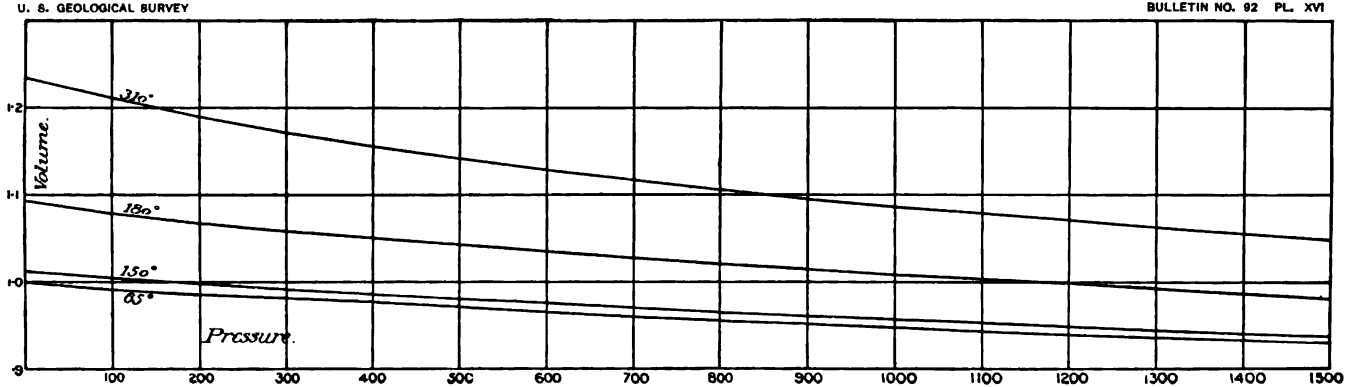
For thymol Table 43, Pl. XVIII and XIX, the results obtained resemble those for paraffin, but the agreement is not so good. The rate is 0·11° C. per atmosphere, when $V_{\theta p} = V_{65,120} = 1{\cdot}04$. Toluidine Table 42, Pl. XVII, shows the rate 0·10 per atmosphere, when $V_{\theta p} = V_{65,120} = 1{\cdot}04$. For diphenylamine finally, Table 41, and Pls. XVI and XIX, the rate is 0·09° C. per atmosphere. In most of the solid substances the expansion difficulties, § 14, render the results inaccurate particularly in cases where two or more distinct threads were observed.

But taking the results as a whole (0° to 185°), it follows with considerable certainty, I think, that *if temperature and pressure vary linearly with each other at the mean rate of about 0·11 C. per atmosphere, there will be no change of volume.* Changes of state of aggregation are excluded from the considerations.

More rigorously this is expressed thus: If with the observed thermal expansion, compressibility be supposed to increase inversely as the first power of the pressure binominal $(1/\alpha + p)$, then temperature and pressure must vary linearly to maintain constancy of volume.

In Pl. XIX the chief isometrics have been grouped together for comparison. The linear march between 0° and 185° is well shown by ether, hol, and paraffin. For toluidine and thymol the irregularities are

Digitized by Google



Isothermals of diphenylamine.

Digitized by Google

Digitized by Google

in an opposite sense, and for thymol the distribution of points is actually zigzag as far as 310°. Hence a march of errors can not be said to be discernible. The break in the undercooled region a, like the break between 185° and 310°, is marked. The latter will be specially discussed in the final paragraph of this chapter in connection with direct data.

The thermodynamic signification of the above results has already been suggested, § 2. It follows, therefore, so far as the present work (§ 40) goes, that the thermodynamic surface $V_{\theta p}$ will probably possess oblique symmetry as shown in Pl. XX. This curve is generated by moving the initial section vp, parallel to itself, but in the oblique direction, so that ten units of pressure may be passed for each unit of temperature. In this motion the left-hand branch of the curve which issues from the plane θ, v would rapidly run up to infinity, so that the surface is everywhere bounded on the left by an oblique infinite plane. This points out a recurrence of the insufficiency of equation (4) already adverted to in § 35. From an inspection of this surface it is, therefore, not possible to deduce the corresponding expression for thermal expansion.

The cause of this difficulty is probably to be referred to the fact that the ratio of θ and p is not independent of $V_{\theta p}$. Hence, in moving the initial section parallel to itself, the curve must be conceived to expand in its own plane in such a way that the oblique horizontal lines described by the consecutive points of the initial curve are not all parallel. In Pl. XX, therefore, 1, 5=3, 7; 2, 6=4, 8; b, e=d, g; etc. But 1, 3, 2, 4, b, d, etc., are not parallel.

DIGRESSION ON THERMAL EXPANSION.

41. *Exponential equation proposed.*—Before proceeding to the computations of the next paragraph, it is convenient to insert a digression here relative to thermal expansion. I made many computations, but the results are much more inaccurate and the equations less satisfactory than was the case with compression. Expansion occurs at a rapidly accelerated rate with temperature, t, in case of low pressures.

Hence the equation

$$\frac{d\frac{v}{V}}{dt}=\frac{\tau}{1-\beta t} \quad \ldots\ldots\ldots\ldots \quad (11)$$

whence

$$\frac{v}{V}=ln\left(1-\beta t\right)^{-\tau/\beta} \quad \ldots\ldots\ldots \quad (12)$$

suggests itself. The first difficulty is the choice of an initial temperature, so that the two equations will be put

$$d\left(\frac{v}{V}\right)/dt=\tau/\left(1-\beta(t-b)\right) \text{ and } v/V=ln\left(1-\beta(t-b)\right)^{-\tau/\beta}$$

Digitized by Google

An application of this equation to the data for ether is given in Table 44, and the difference between observed and calculated inserted above in Table 5. Δp is the pressure increment, the initial pressure being 100 atmospheres. The table is one of double entry, so that ϑ has also been inserted.

TABLE 44.—*Expansion and compression constants of ether.*

t	$\Delta p = 0$.		$\Delta p = 100$.		$\Delta p = 200$.		$\Delta p = 300$.	
	$\tau \times 10^6$.	$\vartheta \times 10^6$.	$\tau \times 10^6$.	$\vartheta \times 10^6$.	$\tau \times 10^6$.	$\vartheta \times 10^6$.	$\tau \times 10^6$.	$\vartheta \times 10^6$.
29°	1,824	165	1,530	165	1,380	165	1,240	165
65°	1,824	226	1,530	226	1,380	226	1,240	226
100°	1,824	343	1,530	343	1,380	343	1,240	343
185°	1,824	1,005	1,530	1,005	1,380	1,005	1,240	1,005
310°	1,824	34,250	1,530	34,250	1,380	34,250	1,240	34,250

$$y_p = ln\left(1+9\vartheta p\right)^{1/9}$$

$$y_t = ln\left(1-2\tau(t-b)\right)^{-\frac{1}{2}} \text{ (nearly)},$$

$$b = 34°$$

It is seen that the change of τ with pressure is less curvilinear and not nearly so rapid as the change of either ϑ or $1/\vartheta$ with temperature. The curve $\left(\frac{v}{V}\right)$ itself, though fitting the extreme results very well, does so less nearly for the moderate expansions under 400 atmospheres, as the expansion under these conditions becomes more rapidly linear than the curve predicates.

Making the final step in these considerations, I supposed that the discrepancies in question might be remedied by a more general form.

$$v/V = ln\frac{(1+\alpha p)^{\vartheta/\alpha}}{\left(1-\beta(t-b)\right)^{\tau/\beta}}$$

whence

$$d\frac{v}{V}dp = \vartheta\Big/\left(1+\alpha p\right)+\left(t-b\right)\frac{\tau}{\beta}\frac{d\beta}{dp}\Big/\left(1-\beta(t-b)\right)$$

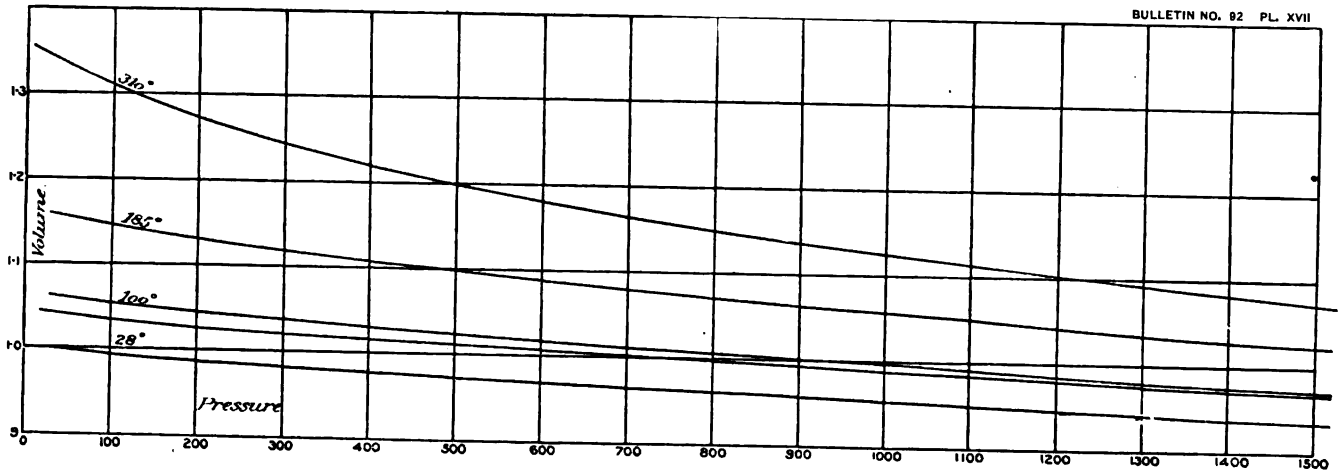
and

$$d\frac{v}{V}/dt = \tau\Big/\left(1-\beta t\right)+p\frac{\vartheta}{\alpha}\frac{d\alpha}{dt}\Big/\left(1+\alpha p\right)$$

But these relations are too complicated to be fruitfully discussed here.

42. *Observed contractions due to cooling under pressure.*—To corroborate the above results as a whole, I will also insert a series of direct

Digitized by Google



Isothermals of toluidine.

Digitized by Google

Digitized by Google

measurements on the contraction of substances, cooling under pressure. Experiments of this kind are difficult. The strain resulting from the continued application of high pressure produces much breakage, either of the parts of the apparatus or of the capillary tubes. It is clear that in method pursued the fiducial volume must be constantly redetermined. I therefore made the experiments at high pressures, alternate with low-pressure experiments, keeping the same interval of pressure and the same thermal environment throughout the series. In Table 45 the results were obtained with a relatively wide capillary, so that the filamentary platinum / platinum-iridium thermo-couple could be drawn *through* the tube, with its junction in the substance. This insures accuracy of thermal measurement; but tubes of this kind can not withstand high pressures. Hence, in subsequent experiments, Tables 46 to 50, the filamentary couple was wrapped around the outside of the capillary in the thermal bath. Temperatures here merely subserve the purpose of coordinating the high and low pressure results. In all the experiments leaks were carefully guarded against and unsatisfactory attempts rejected.

In the tables P is the acting pressure, L the observed length of column, and v_p/V the volume contraction per unit of volume due to P. Temperature θ is given in arbitrary thermoelectric degrees, and $\frac{v}{V}$ are the successive volume decrements due to cooling. A chart accompanies each table. Cooling took place between 185° and 100°, care being taken that at the higher temperature the parts of the tube had been equally heated throughout before the ebullition of the vapor bath was stopped.

Digitized by Google

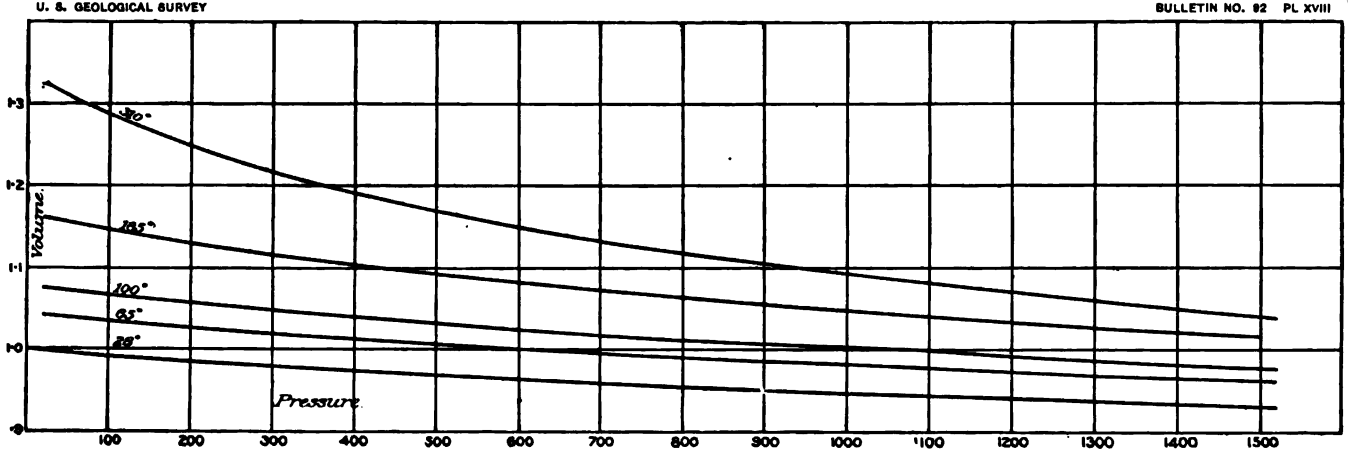
TABLE 45.—*Contraction due to cooling under pressure. Paraffin (first sample).*

	θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$
$P = 150$ atm. $L = 22{\cdot}0^{cm}$. $\frac{v_p}{V} \times 10^3 = 23{\cdot}0$	0	0·0	$P = 150$ atm. $L = 22{\cdot}0^{cm}$. $\frac{v_p}{V} \times 10^3 = 23{\cdot}0$	0	0·0
	2	0·9		2	1·4
	5	2·7		6	3·2
	10	4·1		11	5·5
	16	7·7		18	8·6
	23	10·5		24	10·5
	31	13·2		34	14·1
	48	19·5		50	20 5
	58	24·5		58	24·1
	64	27·3		66	26·8
	72	30·5		74	30·0
	78	32·7		82	33·2
	88	35·9			
	94	39·1			
	102	42·3			
$P = 0$ atm. $L = 22{\cdot}6^{cm}$.	0	0·0			
	7	0·5			
	19	5·3			
	35	12·4			
	54	20·0			
	67	26·5			
	83	33·6			
	99	40·0			
	113	46·0			

TABLE 46.—*Contraction due to cooling under pressure. Paraffin (second sample).*

	θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$
$P = 400$ atm. $L = 19{\cdot}0^{cm}$. $\frac{v_p}{V} \times 10^3 = 57{\cdot}0$	0	57 + 0·0	$P = 0$ atm. $L = 20{\cdot}2^{cm}$.	0	0·0	$P = 400$ atm. $L = 19{\cdot}0^{cm}$. $\frac{v_p}{V} \times 10^3 = 57{\cdot}0$	0	57 + 0·0
	30	1·1		34	2·4		19	1·0
	65	3·7		104	10·0		64	3·2
	115	7·9		154	14·8		154	10·5
	174	12·1		244	23·7		214	14·7
	255	18·9		329	32·2		314	24·2
	325	24·2		424	42·1		404	30·5
	405	30·0		484	48·5		474	36·3
	510	37·9		564	56·4		554	42·6
	585	45·8		614	61·9		604	47·4
	660	52·1		674	68·3		659	52·1
	715	57·9		724	73·7		694	55·8
$l = 0$ atm. $L = 20{\cdot}2^{cm}$.	0	0·0	$P = 400$ atm. $L = 19{\cdot}0^{cm}$. $\frac{v_p}{V} \times 10^3 = 57{\cdot}0$	0	57 + 0·0			
	15	1·0		24	3·2			
	65	6·0		64	5·3			
	140	14·3		149	11·6			
	240	23·3		239	19·0			
	320	30·7		314	23·7			
	410	39·6		414	31·6			
	470	46·5		484	40·0			
	550	54·9		564	45·3			
	605	60·4		664	54·7			
	660	66·8		709	60·0			
	720	72·8						
	770	78·7						
$P = 400$ atm. $L = 19{\cdot}0^{cm}$. $\frac{v_p}{V} \times 10^3 = 57{\cdot}0$	0	57 + 0·0	$P = 0$ atm. $L = 20{\cdot}2^{cm}$.	0	0·0			
	30	3·7		34	2·0			
	85	7·4		84	6·9			
	175	13·2		134	12·4			
	260	21·1		234	22·3			
	345	26·8		309	30·2			
	425	34·2		394	38·6			
	495	39·5		474	46·5			
	565	44·7		544	53·9			
	660	54·2		609	60·9			
	720	59·5		669	67·3			
				714	72·3			

Digitized by Google



Isothermals of thymol.

Digitized by Google

Digitized by Google

TABLE 47.—*Contraction due to cooling under pressure. Paraffin (third sample).*

	θ	$\frac{v}{V}\times10^3$		θ	$\frac{v}{V}\times10^3$		θ	$\frac{v}{V}\times10^3$
400 atm. 21·3cm. $10^3=52·9$	0	0·0	$P=500$ atm. $L=21·1$cm. $\frac{v_p}{V}\times10^3=62·7$	0	0·0	$P=600$ atm. $L=20·8$cm. $\frac{v_p}{V}\times10^3=72·4$	0	0·0
	13	0·1		20	1·9		18	*0·0
	43	2·4		52	3·8		58	4·3
	98	7·0		109	9·0		140	9·1
	178	13·2		192	14·7		200	14·0
	266	21·1		277	20·9		270	20·2
	348	27·7		327	25·1		335	25·5
	433	33·8		392	30·0		405	30·3
	504	40·0		458	34·6		450	34·2
	603	48·3		507	38·4		515	38·0
				558	42·6		570	42·8
20 atm. 22·5cm. $10^3=0$	0	0·0	$P=20$ atm. $L=22·5$cm. $\frac{v_p}{V}\times10^3=0$	0	0·0	$P=20$ atm. $L=22·5$cm. $\frac{v_p}{V}\times10^3=0$	0	0·0
	14	0·5		15	1·0		15	2·2
	48	5.3		51	6·0		55	5·8
	103	10·7		105	17·8		145	15·6
	178	18·2		240	25·3		235	25·3
	306	31·1		313	33·3		320	33·3
	378	37·8		375	39·0			
	456	46·2		440	45·0	$P=600$ atm. $L=20·8$cm. $\frac{v_p}{V}\times10^3=72·4$	0	0·0
	526	53·8		500	51·1		13	2·0
	623	63·6		555	57·8		(**)	....
00 atm. 1·3cm. $10^3=52·9$	0	0·0	$P=500$ atm. $L=21·1$cm. $\frac{v_p}{V}\times10^3=62·7$	0	0·0			
	18	1·0		32	3·8			
	68	5·6		85	8·0			
	128	10·3		148	11·8			
	202	16·4		217	17·5			
	314	24·4		290	22·7			
	410	32·4		351	27·5			
	513	41·3		415	32·7			
	567	45·1		480	37·9			
	622	50·0		545	42·6			
	662	54·4						

* Tube slips (?). ** Tube breaks.

Rates of contraction.

P	$\Delta\theta$	$\Delta\frac{v}{V}\times10^3$
20	500	51·1
400	500	41·1
500	500	38·7
600	500	37·7

Digitized by Google

TABLE 48.—*Contraction due to cooling under pressure. Paraffin (fourth sample, closed capillary tube).*

	θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$
$P = 200$ atm. $L = 18{\cdot}3^{cm}$. $\frac{v_p}{V} \times 10^3 = 28{\cdot}7$	0	0·0	$P = 200$ atm. $L = 17{\cdot}8^{cm}$. $\frac{v_p}{V} \times 10^3 = 28{\cdot}7$	0	0·0	$P = 20$ atm. $L = 18{\cdot}8^{cm}$.	0	0·0
	15	1·6		15	2·7		26	2·7
	120	10·4		56	6·1		85	9·6
	165	16·4		130	13·7		148	16·0
	242	23·5		188	18·1		210	22·9
	297	28·4		250	23·5		280	30·3
	370	33·9		370	34·4		330	35·1
	412	38·3		430	39·9		382	41·0
	466	43·2		491	45·4		440	46·3
	514	47·5					490	51·6
							540	56·9
$P = 20$ atm. $L = 18{\cdot}8^{cm}$.	0	0·0	$P = 400$ atm. $L = 17{\cdot}8^{cm}$. $\frac{v_p}{V} \times 10^3 = 53{\cdot}2$	0	0·0	$P = 400$ atm. $L = 17{\cdot}8^{cm}$. $\frac{v_p}{V} \times 10^3 = 53{\cdot}2$	0	0·0
	16	2·7		20	0·6		26	1·2
	70	8·5		80	5·6		73	6·2
	112	13·3		129	10·1		125	8·9
	185	21·8		190	14·0		192	14·0
	227	26·1		250	19·6		260	19·6
	294	33·0		315	24·1		315	23·5
	360	39·9		372	28·5		380	29·1
	442	48·4		430	33·0		435	34·1
	488	53·2		482	38·0		480	36.9
	525	56·9		530	40·8		520	40·2
							560	43·1

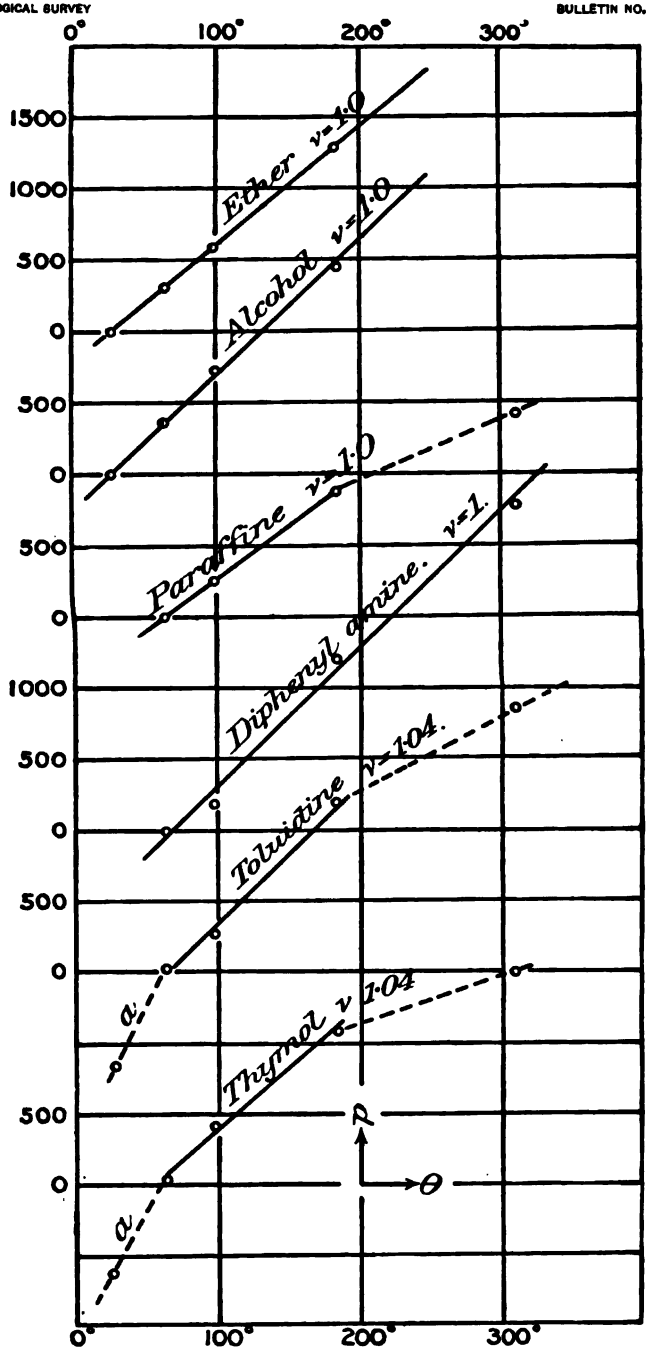
TABLE 49.—*Contraction due to cooling under pressure. Naphthalene.*

	θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$
$P = 400$ atm. $L = 20{\cdot}4^{cm}$. $\frac{v_p}{V} \times 10^3 = 37$	0	0·0	$P = 20$ atm. $L = 21{\cdot}1^{cm}$.	0	0·0	$P = 400$ atm. $L = 20{\cdot}3^{cm}$. $\frac{v_p}{V} \times 10^3 = 37$	0	0·0
	35	3·4		38	2·4		29	2·0
	85	6·9		88	6·1		69	4·4
	170	13·3		178	13·2		184	13·3
	250	18·7		270	20·9		254	18·7
	345	26·6		354	28·0		334	24·6
	435	33·0		428	34·6		411	31·0
	505	39·9		503	41·7		490	38·9
	575	46·8		568	48·8		566	45·3
	624	50·2		638	55·9		616	48·3
	677	55·1		678	60·2		689	55·6
$P = 20$ atm. $L = 21{\cdot}1^{cm}$.	0	0·0	$P = 400$ atm. $L = 20{\cdot}3^{cm}$. $\frac{v_p}{V} \times 10^3 = 37$	0	0·0			
	24	0·5		35	2·0			
	57	4·2		105	6·4			
	142	11·3		185	12·3			
	209	17·1		270	17·2			
	302	24·2		355	24·1			
	382	31·3		485	36·4			
	481	39·8		545	42·4			
	539	45·0		615	46·8			
	594	51·2		675	54·2			
	648	56·9		730	61·5			
$P = 400$ atm. $L = 20{\cdot}4^{cm}$. $\frac{v_p}{V} \times 10^3 = 37$	0	0·0	$P = 20$ atm. $L = 21{\cdot}1^{cm}$.	0	0·0			
	40	4·4		35	1·9			
	112	9·4		93	6·2			
	175	13·8		167	13·3			
	262	19·7		245	19·5			
	348	26·1		415	35·1			
	420	33·0		493	41·2			
	507	39·4		577	48·8			
	585	45·8		615	53·5			
	638	50·7		683	60·7			
	695	57·6						

Relative rates (initial).

P.	$\Delta\theta$.	$\Delta \frac{v}{V} \times 10^3$
20	500	41·0
400	500	36·6

Digitized by Google



Isometrics of ether, alcohol, paraffin, diphenylamine, toluidine, and thymol compared.

Digitized by Google

Digitized by Google

TABLE 50.—*Contraction due to cooling under pressure monochlor acetic acid.*

	θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$		θ	$\frac{v}{V} \times 10^3$
$P=200$ atm. $L=20{\cdot}7^{cm}$.	0	0·0	$P=430$ atm. $L=20{\cdot}3^{cm}$.	0	0·0	$P=600$ atm. $L=19{\cdot}9^{cm}$	0	0·0
	10	1·9		29	3·4		10	1·5
	50	7·2		166	17·8		40	7·1
	100	13·5		266	29·6		100	12·6
	168	21·3		336	37·4		105	20·1
	238	29·5		402	44·3		233	26·6
	316	38·6		466	52·3		300	34.2
	366	44·9		516	58·6		357	40·7
	427	52·2		556	63·9		428	48·7
	480	58·5		603	60·0		485	53·8
	528	64·8		641	74·9		539	60·4
$P=20$ atm. $L=21{\cdot}2^{cm}$.	0	0·0	$P=20$ atm. $L=21{\cdot}2^{cm}$.	0	0·0	$P=20$ atm. $L=21{\cdot}1^{cm}$.	0	0·0
	18	1·9		13	1·4		29	4·8
	53	7·5		48	7·1		85	12·7
	108	15·1		104	14·2		155	22·2
	192	25·0		168	23·2		225	30.7
	256	33·1		248	32·5		285	39·6
	318	41·1		316	41·1		353	49.1
	377	49·1		368	48.2		415	57·1
	503	66·5		431	56.1		487	64·6
	528	69·9		483	63·2		535	70·3
	598	78·4		538	70·8		600	79·8
$P=200$ atm. $L=20{\cdot}7^{cm}$	0	0·0	$P=400$ atm. $L=20{\cdot}3^{cm}$.	0	0·0	$P=600$ atm. $L=$ ———.	0	0·0
	27	2·9		35	3·5		20	2·0
	72	8·2		75	7·4		70	8·1
	134	15·5		145	15·3		195	21·1
	208	24·6		217	23·2		265	29·6
	277	32·4		295	32·1		335	37·2
	342	40·6		370	40·4		405	45·2
	400	46·9		403	44·3		453	50·3
	462	51·6		460	51·3		500	55·3
	548	66·2		520	58·1		545	60·9
	574	68·6						

P.	$\Delta\theta$	$\Delta \frac{v}{V} \times 10^3$
20	500	64·8
200	500	59·8
400	500	58·5
600	500	54·5

These data very fully corroborate each other and the statements of the above §§ 23, 30, 31, 35 and 41. Contraction under pressure when referred to unit of volume at the initial (high) temperature, decreases at a rapid rate with pressure. In case of paraffin, were the observed conditions to hold indefinitely, contraction would altogether cease at a pressure less than 2,000 atmospheres. This follows in a less pronounced degree for naphthalene and chloracetic acid. The lines of cooling for the same low pressure are parallel.

COMPRESSIBILITY INCREASING INVERSELY AS THE SECOND POWER OF THE PRESSURE BINOMINAL.

43. *Properties of the hyperbolic equation.*—The expression $v/V = ln\,(1 + \alpha p)^{\theta/\alpha}$, as utilized in § 39, furnishes a family of curves which must in their ultimate contours necessarily fall below the corresponding isothermals of the substance under discussion. It is the object of the

Digitized by Google

present section to investigate a similar family, the ultimate contours of which must be above the actual isothermals. This may be done by assuming

$$\frac{d\frac{v}{V}}{dp} = \frac{\mu}{(1+\nu p)^2} \quad \ldots\ldots\ldots\ldots \quad (1)$$

whence by integration

$$v/V = \frac{\mu p}{1+\nu p} \quad \ldots\ldots\ldots\ldots \quad (2)$$

In this case when $p=\infty$, $(v/V)_{p=\infty} = \mu/\nu$, or, as will be seen in the following tables, $(v/V)_{p=\infty} = 2/9$. In the actual case, v/V, though it can not be greater than 1, will in all probability eventually exceed 2/9.

The method of discussion to be adopted is similar to that in the foregoing section.

Suppose in the first place that

$$y_0 = \mu_0 p_0/(1+\nu p_0)$$

and

$$y' = \mu_0 (p_0+p)/\Big(1+\nu(p_0+)\Big).$$

Then

$$y = y' - y_0 = \mu_0 p \Big/ \Big(1+\nu p_0\Big)\Big(1+\frac{\nu_0}{1+\nu_0 p_0} p\Big),$$

or if

$$\mu = \mu_0/(1+\nu_0 p_0)^2 \text{ and } \nu = \nu_0 (1+\nu_0 p_0) \quad \ldots\ldots \quad (3)$$

there results

$$y = \mu p/(1+\nu p),$$

which is identical with the form (1). Hence if p_0 and p are consecutive pressure intervals between 0 and $p+p_0$, then the constants obtained from observation within the interval p may be reduced to those applying for the whole interval by equations (3), or the equivalent expressions

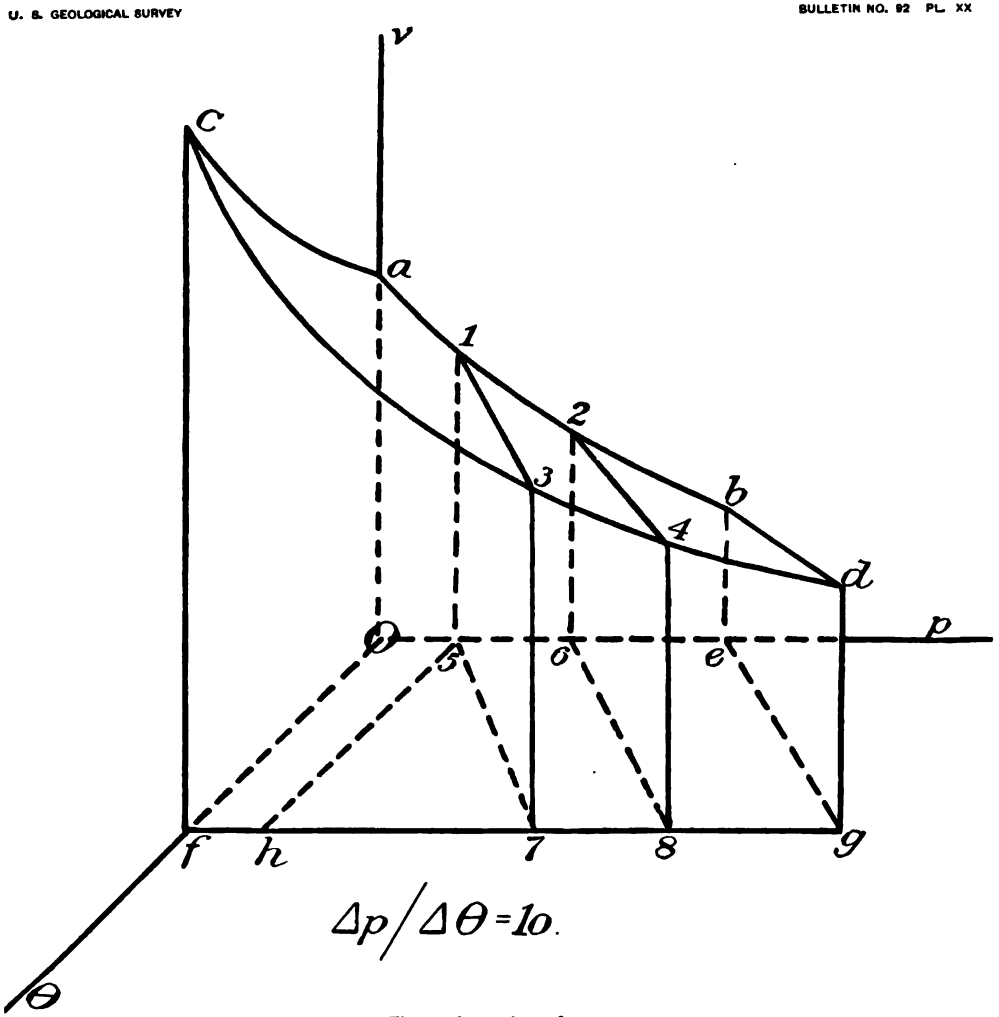
$$\mu_0 = \mu/\overline{1-\nu p_0^2} \quad \nu_0 = \nu/\overline{1-\nu p_0} \quad \ldots\ldots \quad (4)$$

44. *Presumptive character of the isometrics.*—According to Mendeleef, Thorpe, and Rücker (l. c.) the volume of liquids in case of thermal expansion may be represented by

$$V_\theta = 1/(1-k\theta) \quad \ldots\ldots\ldots\ldots \quad (5)$$

where pressure is constant. Here V_θ is the actual volume, θ the temperature and k the specific constant. Introducing equation (1)

Digitized by Google



Thermodynamic surface.

Digitized by Google

Digitized by Google

and denoting by V the volume for the pressure p and temperature θ, I obtain

$$V = \frac{1 + (\nu - \mu)p}{(1 - k\theta)(1 + \nu p)},$$

which for pressures and temperatures not too great may be put

$$V = \frac{1 + (\nu - \mu)p}{1 - k\theta + \nu p}.$$

If therefore $V = V_c = \text{constant}$,

$$\theta = -\frac{1 - V_c}{kV_c} + p\,\frac{\nu(1 - V_c) - \mu}{kV_c} \quad \ldots \quad (6)$$

so that in case of constant volume temperature varies linearly with pressure, small intervals of variation presupposed. The rigorous deduction of (1) and (5) is

$$\theta = -\frac{1 - V_c}{kV_c} - \frac{\mu}{kV_c}\,\frac{p}{1 + \nu p} \quad \ldots \quad (7)$$

which is linear in proportion as νp is small compared with 1. In § 40 it has been shown that the relation of θ to p is probably linear throughout a much greater interval. Hence it follows that equation (1) is insufficient for large pressures.

Regarding equation (5) it follows that if θ_0 and θ be two consecutive intervals of temperature, the former measured from zero, and if

$$V_{\theta_0} = 1/(1 - k_0\theta_0),\ V'_\theta = 1/\Big(1 - k_0(\theta_0 + \theta)\Big),$$

and

$$k = k_0/\overline{1 - k_0\theta_0},$$

then

$$V_\theta = 1 + (V'_\theta - V_\theta\theta) = \frac{1 + k^2\theta_0\theta}{1 - k\theta}$$

Equation (8) with the exception of the corrective member $k^2\theta_0\theta/(1 - k\theta)$ has the same form as (5). Hence the observations may be referred to any convenient temperature as a point of departure.

45. *Hyperbolic constants computed.*—Applying equation (1) § 43 to the observations in §§ 16, 17, 19, 20, 23, 25, which are the most complete in hand, I obtained the constants given in Table 51. It is clear that ν must be some function of μ; but the observations are too crude to indicate the precise nature of this function. If ν be plotted as dependent on μ, the points are seen to group themselves about a straight line passing through the origin. Again if the ratios ν/μ be found, the consecutive results show no discernible march or grouping. Hence I have assumed the ratio as constant, and have added its mean value in the table.

Digitized by Google

The ether and the alcohol points for 310° are not amenable to this method of treatment, and the discrepancy is somewhat apparent in the ether point for 185°. In case of alcohol the relation of constants is irregular, showing unusually large errors of observation.

TABLE 51.—*Hyperbolic constants which reproduce the isothermal decrements. Direct computation.*

$$v/V = \mu p\ (1+\nu p).$$

Temp.	$\mu \times 10^6$	$\nu \times 10^6$	Temp.	$\mu \times 10^6$	$\nu \times 10^6$	Temp.	$\mu \times 10^6$	$\nu \times 10^6$
	Ether.			Toluidine.			Paraffin.	
29°	169·0	830	28°	56·5	58	65°	85·1	191
65°	228·2	1,028	65°	70·0	413	100°	111·5	475
100°	352·9	1,573	100°	81·4	110	185°	181·5	845
185°	1,027·6	3,870	185°	145·6	801	310°	368·1	1,510
*310°	10,842·0	18,400	310°	401·1	1,730			
	Alcohol.			Diphenylamine.			Thymol.	
28°	87·0	243	65°	61·3	162	28°	67·8	465
65°	111·5	276	100°	69·3	285	65°	69·5	157
100°	181·7	1,630	185°	114·4	613	100°	99·3	553
185°	348·2	1,755	310°	214·6	889	185°	162·5	715
*310°	7,553·0	15,770				310°	465·2	2,009

* Exceptional values due to partial adiabatic expansion.

Mean ratio $\frac{\nu}{\mu} = 4{\cdot}5$.

46. *Mean hyperbolic constants derived.*—The next table, 52, contains the values of μ obtained by accepting the equation $\nu = 4{\cdot}5\ \mu$, derived at the end of the last table. The exceptional alcohol and ether points have been rejected. In general it will be seen that the diagram of μ and ν is not so smooth as was Plate XII, in § 37, for α and S. This shows, I think, that the equation of the last section is more in keeping with the character of the observations made, than is the equation of this section.

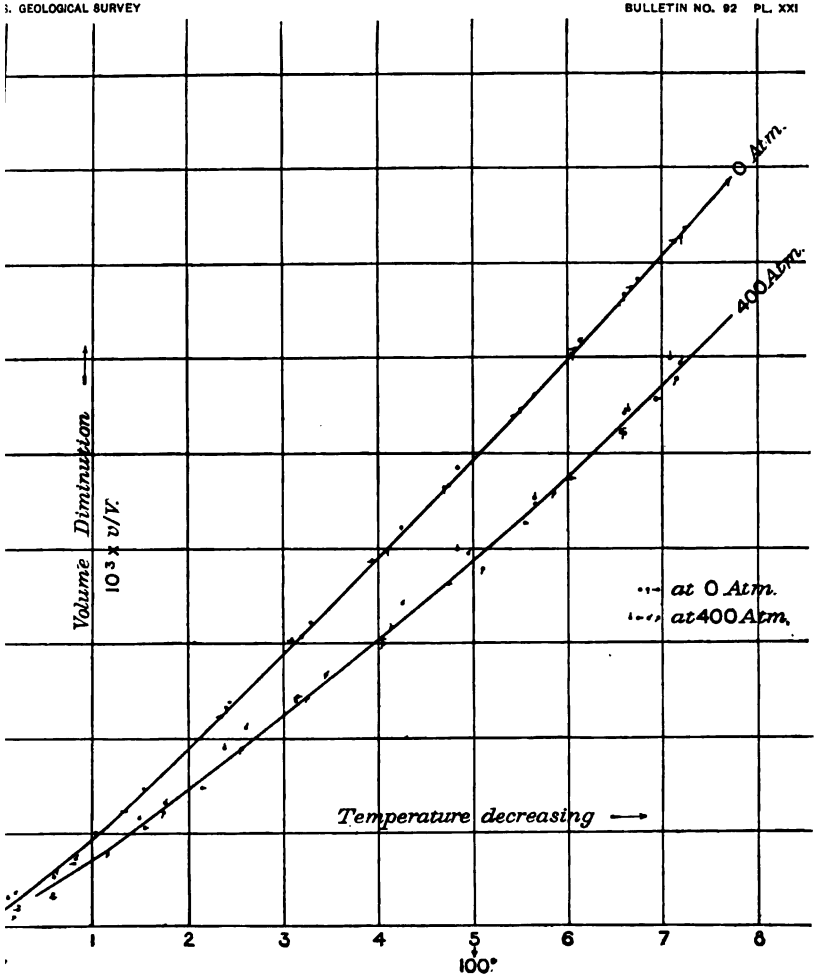
TABLE 52.—*Mean hyperbolic constants.*

$$v\ V = \frac{\mu p}{(1+4{\cdot}5\mu p)}$$

Substance.	θ	$\mu \times 10^6$	Substance.	θ	$\mu \times 10^6$	Substance.	θ	$\mu \times 10^6$
Ether	29°	167	Toluidine-para	28°	50	Paraffin	65°	88
	65°	229		65°	69		100°	112
	100°	354		100°	83		185°	181
	*185°	1,221		185°	141		310°	382
	310°	.....		310°	412			
Alcohol	28°	89	Diphenylamine	65°	64	Thymol	28°	66
	65°	115		100°	69		65°	73
	100°	163		185°	112		100°	97
	185°	340		310°	216		185°	162
	310°	.....					310°	481

* Equation begins to fail.

Digitized by Google



Contraction on cooling. Paraffin.

Digitized by Google

Digitized by Google

47.—*The isothermal band.*—Making use of the constants in Table 52, I calculated the actual isothermals in the way suggested in § 39. The expansions are directly observed, and the only hypothesis introduced is equation 1, § 43. The results so obtained are inserted in Tables 38 to 43, where $V_{\mu\theta}$ are the actual volumes obtained by the hyperbolic equation § 43, and $V_{\nu\theta}$ refer to the exponential equation, § 35. These two quantities, constituting the upper and lower limit of the isothermal band, are to be discussed together somewhat in detail.

In case of ether the divergence or width of the band at 1,000 atmospheres is about 0·4% at 28°, 1% at 65°, and 1% at 100°. At 185° the divergence would be 8%, but the hyperbola here begins to fail. Better accordance could here be obtained as far as 185° by introducing $\nu = 0{\cdot}0003 + \frac{5}{14}\mu$, as found from Table 51; but in consequence of the labor already spent I desisted from this additional trial. My purposes are sufficiently answered by the above computation. Constructing the relations (isometrics) for p and θ when $V_c = 1$, it will be seen that whereas in the case of the exponential formula the straight line is predicted even as far as 185° and 1,300 atmospheres, this is not the case for the hyperbolic form. Divergence from the linear curve begins very appreciable at 100° and 600 atmospheres.

In case of alcohol the conformity of results is better throughout. At 1,000 atmospheres the curves for 28° do not diverge; at 65° the divergence is 0·2%; at 100°, 0·3%; at 185°, 2%. Putting $V_c = 1$, it appears that whereas the exponential relation holds linearly as far as 185° and 1,500 atmospheres, the hyperbolic equation holds only as far as 100° and 700 atmospheres.

Divergence in case of paraffin at 1,000 atmospheres is 0·1% at 65°; 0·2% at 100°; 0·7% at 185°; 6% at 310°. As far as 185° and 900 atmospheres both isometrics are linear. At 310° both fail, but on opposite sides of the isometric. The agreement of the exponential is preferable throughout.

The observations for diphenylamine are less satisfactory, partly because of the choice of 0 atmospheres as initial pressure, partly because of some error in the expansion data. At 1,000 atmospheres the divergence of curves is 0·1% at 65°; 0·1% at 100°; 0·2% at 185°; 1% at 310°. The interesting feature of these results is the fact that the isometrics seem to retain their linear character as far as 310°.

In case of thymol the divergence at 1,000 atmospheres is 0·1% at 28°; 0·2% at 65°; 0·1% at 100°; 0·6% at 185°; 3% at 310°. Irregularities in expansion have also distorted these results.

Finally, in case of para-toluidine the divergence at 1,000 atmospheres at 28° is nil; at 65°, nil; at 100°, 0·3%; at 185°, 0·3%; at 310°, 3%.

48. *Conclusion.*—Summarizing these results, it appears that the exponential $v/V = ln(1+\alpha p)^{\theta/\alpha}$ is more in keeping with the general character of the isothermals discussed than is the hyperbolic form $v/V = \mu p/(1+\nu p)$. Both equations fail at 310°. It is difficult to assign

Digitized by Google

a reason for this. It is not probably due to occluded air since the substances were boiled and introduced into a hot capillary tube. Moreover, in case of mercury (Table 3) an air-bubble discrepancy if present would necessarily have shown itself at 310°. The error, due to the fact that my curves must be in some small part adiabatic, would induce too slow a variation of volume and hence emphasize the high temperature break of the isometrics. There may be dissociation of many of the above organic substances at this high temperature. Azo-benzol, for instance, actually decomposes and turns black at 310°. But just what the effect of dissociation will be, in modifying the computed isothermal, is not easily conjectured, for the greater compressibility resulting is compensated by larger initial volumes. The high temperature break might result from inconstancy of temperature in the boiling tube. I did not explore the distribution of temperature, for the behavior was such that I had no reason to suspect inconstancy.

To interpret these discrepancies I resolved to make direct measurements for ether, a case in which the high temperature break is most pronounced. Finding a tube which was strong enough to resist 1,000 atmospheres at 310°, I obtained the following example, Table 53, of many similar results. The volumes are all referred to unit of volume at 100 atmospheres and 22°. To reduce them to 100 atmospheres and 29° (which hold for the above designated isothermals, Table 38), the volumes at 300° must be decreased about 1·5%. By doing this I obtain the "observed" isothermal inserted in Pl. XIV, Fig. 1. Since the length of thread L is now only 1·85^{cm}, the low temperature isothermal can not be accurately given. The tube broke, in my final endeavors to repeat the experiments, in such a way to exclude adiabatic conditions.

TABLE 53.—*Isothermals of ether. Direct measurement.* $\theta = 300°$; $L = 6·00^{cm}$.

p	Volume.	Volume.	p	Volume.	Volume.	p	Volume.	Volume.
atm.			*atm.*			*atm.*		
100....	3·30	3·12	400....	1·43	1·41	700....	1·24	1·23
200....	1·83	1·76	500....	1·34	1·32	800....	1·19	1·19
300....	1·56	1·52	600....	1·28	1·26	900....	1·16	1·16

$\theta = 22°$; $L = 1·85^{cm}$.

100....	1·00	1·00	300....	·97	·97			
200....	·99	·99	400....	·96	·96			

It follows from this table that the 300° point of the ether isometric may be looked for in the region of 2,000 atmospheres. Hence the observed results substantiate the computed isometric for ether given in Plate XIV, which predicts the corresponding point at about 2,200 atmospheres. Nevertheless it can not be too carefully noted that if the isometrics for volumes 1·2, 1·3, 1·4 · · · be constructed (185° and 310° being now available) the break between 185° and 310° remains in full force, quite in conformity with the other data (alcohol, paraffin,

Digitized by Google

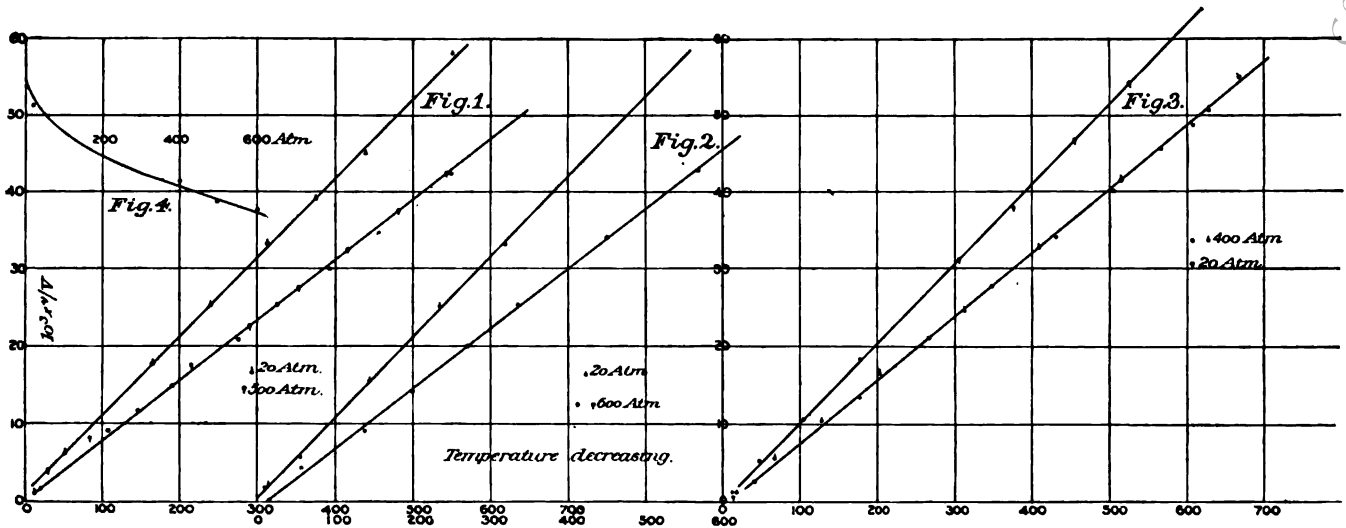


FIG. 1. Contraction on cooling under pressure. Paraffin. 20 and 400 atmospheres.
FIG. 2. Contraction on cooling under pressure. 20 and 500 atmospheres.
FIG. 3. Contraction on cooling under pressure. 20 and 600 atmospheres.
FIG. 4. Relative rates of contraction. Paraffin.

Digitized by Google

Digitized by Google

etc.). The full explanation of the occurrences here met with is of exceedingly great importance in its geological bearing and will therefore be made the subject of my subsequent work. Curved isometrics lead to certain interesting conditions of maximum volume.

The chief observational discrepancy encountered in these results is the expansion error in case of substances which solidify between observations at different temperatures. Hence the effect of different volumes on the slope of the isometrics can not be satisfactorily discussed. Since compression measurements retain their value independent of the thermal expansions and since the method pursued is such that all necessary measurement for thermal expansion can be made at atmospheric pressure, the difficulties may easily be rectified. By using a thermometer tube the purely thermal data can be supplied with any desired degree of accuracy. This I conceive to be the advantage of the mode of investigation set forth in the present paper.

Among the important results of the above tables is the fact that compressibility moves on the even tenor of its way quite independent of normal boiling points and melting points, provided of course the conditions are not such that boiling and melting can actually occur. For this reason compressibility is particularly adapted for exploring the nature of the environment of the molecule in its relations to temperature, i. e. for exhibiting the character of the thermal changes of the molecular fields of force.

49. The above work, though confined to relatively low ranges of pressure, was believed to have a more general value for reasons such as these: Instead of tracing the isothermals of a single substance throughout enormous ranges of pressure, similarly comparable results may possibly be obtained by examining different substances, conceived to exist in as widely different thermal states as possible. For in such a case, inasmuch as the actual or total pressure is the sum of the pressures applied externally and the internal pressure, the total pressure in question virtually varies enormously. This calls to mind the remarks made in §§ 35 and 43 relative to observations confined to limited parts of an isothermal.

Finally, the work of the present paper may be looked at from quite a different point of view. Suppose, for instance, I regard the linear isometric proposed by Ramsey and Young (loc. cit.) as an established fact. Then the chief result of the present work, viz, that the exponential equation (2) if applied to the observed changes of volume predicts a linear isometric throughout an enormous range of pressure, affords favorable evidence of the probable truth of the exponential equation in question. In other words, it is probable that along any isothermal compressibility increases inversely as pressure augmented by a constant. The interpretation of this constant can not now be given.

Digitized by Google

CHAPTER II.

THE EFFECT OF PRESSURE ON THE ELECTRICAL CONDUCTIVITY OF MERCURY.

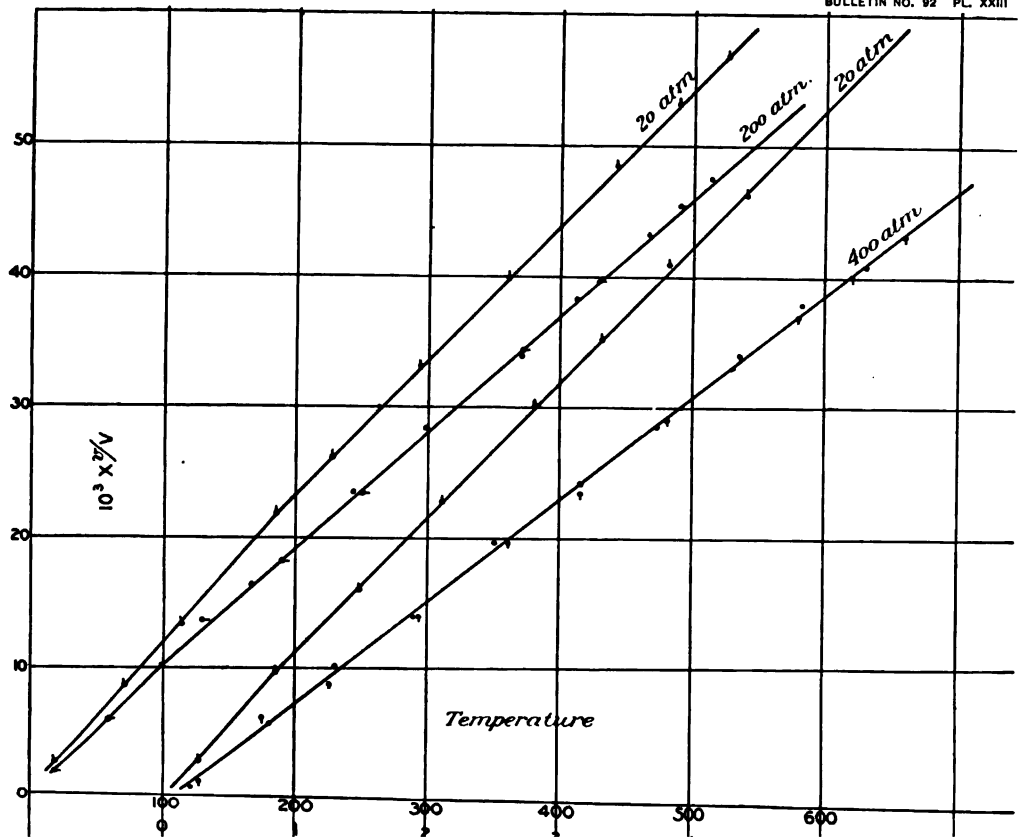
INTRODUCTORY.

50. ***Purposes of the work.***—In the endeavor to obtain data for the relation between melting point and pressure, a question which in its higher phases is of extreme geological importance, the difficulties of the general problem make it advisable to begin with material which can easily be operated on. Mercury suggests itself at once. Its melting point is very low, at temperatures where most resinous cements, marine glue for instance, are practically rigid. This greatly facilitates the construction of high-pressure apparatus, and the experiments therefore become of a less formidable character. The molecular structure of the metal is relatively simple, which is another advantage. Apart from practical considerations the behavior of any substance of definite character has its own intrinsic importance and must contribute essentially to a general diagram of the fusion phenomena in question.

Again, mercury in common with many other metals (K, Na, Sn, etc.) shows a marked increase of electrical resistance on passing from the solid to the liquid condition. Indeed the resistance of the liquid may be from two to five times that of the solid metal, as the researches of Matteuci, Matthiessen, Siemens, L. de la Rive, Cailletet and Bouty,[1] C. L. Weber,[2] Grunmach,[3] and others show. The change of resistance in question may therefore be expediently selected as a *criterion of fusion*, a principle which may be used, cautiously of course, in the cases of metals and even of some solid electrolytes. The conductivity of glass, for instance, increases at a phenomenally rapid rate while the solid passes through the viscous stages into fluidity (Buff, Beetz, Gray, Foussereau, Perry, and others[4]). From all this it follows that the somewhat cumbersome problem of *melting point and pressure* may in many instances be translated into *electrical resistance and pressure*, a form in

[1] Cailletet and Bouty: C. R., vol. 100, 1885, p. 1188.
[2] C. L. Weber: Wied. Ann., vol. 25, 1888, p. 245; ibid., vol. 37, 1889, p. 587; ibid., vol. 38, 1889, p. 227.
[3] Grunmach: Wied. Ann., vol. 35, 1888, p. 764; ibid., vol. 36, 1889, p. 587; ibid., vol. 37, 1889, p. 508.
[4] The literature is given in my paper on stressed glass (Am. Jour. Sci., vol. 37, 1889, pp. 339, 340).

Digitized by Google



Digitized by Google

Digitized by Google

which it is much better adapted for experimental attack. This indicates the general trend of my present work.

The present chapter shows this method to be feasible. I measure the effect of pressure on the conductivity of mercury at ordinary temperatures, the results of which work afford a sufficient preliminary test.

51. *Literature.*—The effect of pressure on the conductivity of liquid metals is not well known. Chwolson[1] operated on solid metals, obtaining results of ·01% (copper and brass) to ·1% (lead), per 100 atmospheres. These data are too small to be of practical use of the kind above in view, except in the case of lead perhaps. They are too easily distorted by the thermal effect of compression. Compared with my results for liquid mercury they suggest that distinctions between the solid and the liquid states may perhaps be feasible in a scale of compressibility. R. Lenz,[2] operating on mercury, found a diminution of resistance of 2% per 100 atmospheres, proportional to the pressure of 1 to 60 atmospheres, a very favorably large result quite in keeping with my purposes. E. Pfeiffer,[3] using Cailletet's pump, communicates a method for the measurement of electrolytic resistance under pressure, and data for an aqueous solution of CO_2. J. W. Clarke[4] electrolyzed dilute sulphuric acid in a closed space. L. Graetz[5], taking a somewhat different line of departure, endeavors to arrive at the effect of pressure on the resistance of solid salts.

Foussereau[6] discovered some remarkable effects of long continued high pressure (175 atmospheres) on the conductivity of metallic chlorides (Fe, Al) in very dilute solution. The effect of pressure on the resistance of carbon, which lies beyond the present work, has been studied by Mendenhall[7] and others.

This practically closes the list of more or less closely allied researches. The results of R. Lenz seem, therefore, to be the only special data in hand. Again, a study of the combined effect of temperature near the melting point of a metal and the superincumbent pressure has never been made.

SIMPLE METHODS AND RESULTS.

52. *Cailletet's tubes described.*—My first experiments were made with Cailletet's oxygen tubes, into the small end of which a platinum terminal was either fused or cemented with marine glue. The tubes themselves proved to be badly annealed and unexpectedly fragile when subjected to high pressure. I therefore took Prof. Rood's precaution of annealing them at 450°, until traces of polarization disappeared. For this purpose it was convenient to cover the glass with

[1] Chwolson: Carl's Reportorium, vol. 14, 1878, p. 26. 27. Beiblätter, vol. 5, 1881, p. 449.
[2] R. Lenz: Beiblätter, vol. 6, 1882, p. 802. Original (Stuttgart, 1882) not accessible.
[3] Pfeiffer: Wied. Ann., vol. 23, 1884, p. 625.
[4] Clarke: Phil. Mag. (5), vol. 20, 1885, p. 435.
[5] Graetz: Wied. Ann., vol. 29, 1886, p. 314.
[6] Foussereau: C. R., vol. 104, 1887, p. 1161.
[7] Mendenhall: Am. Jour. Sci., 3d ser., vol. 24, 1882, p. 42.

Digitized by Google

asbestus, surround this with a piece of iron gaspipe also covered with asbestus, and then expose it in a combustion furnace, Fletcher's being preferable. In spite of all precautionary preparation, I found the tubes in hand (external diameter $2\rho_2 = 1{\cdot}8^{cm}$, internal diameter $2\rho_1 = 0{\cdot}17^{cm}$) to be incapable of withstanding more than 200 atmospheres internal pressure. In future experiments it will therefore be necessary to take advantage of smaller diameters.

Instead of platinum, amalgamated zinc terminals were used in case of the zinc sulphate solutions.

53 *Electrical apparatus.*—The tubes were made part of a Wheatstone bridge of which the corresponding branch was a suitable rheostat X. If $a/b = x/R$, and if I know the deflections of the galvanometer for any increment δx, I can at once compute the quantity δR produced by a given pressure. For in the case of like deflections, $\delta x/x = \delta R/R$. By this simple and convenient method I obtained the data of Table 54, by alternately increasing and decreasing the pressure by increments of 25 atmospheres each. In Table 54, δp is the increment of pressure in atmospheres, practically in megadynes per square centimeter, since the Bourdon gauge (§ 9, 10) used is neither absolute nor very sensitive. $\delta R/R$ is the corresponding increment of resistance for each δp. By adding to $\delta R/R$ the correction $\delta r/r$ due to the expansion of the glass tube (the method of computing $\delta r/r$ will presently be shown, § 55) I obtain the final column $\delta R_0/R_0$, or the resistance effect of the hydrostatic pressure p. I may state that my galvanometer, in case of mercury, was sensitive enough to show deflections of 21^{cm} readable to $0{\cdot}01^{cm}$ per 100 atmospheres.

54. *Preliminary data.*—The initial pressure in the following table is 25 atmospheres, insuring fixed positions of parts, and absence of small air bubbles. Commercial mercury was used.

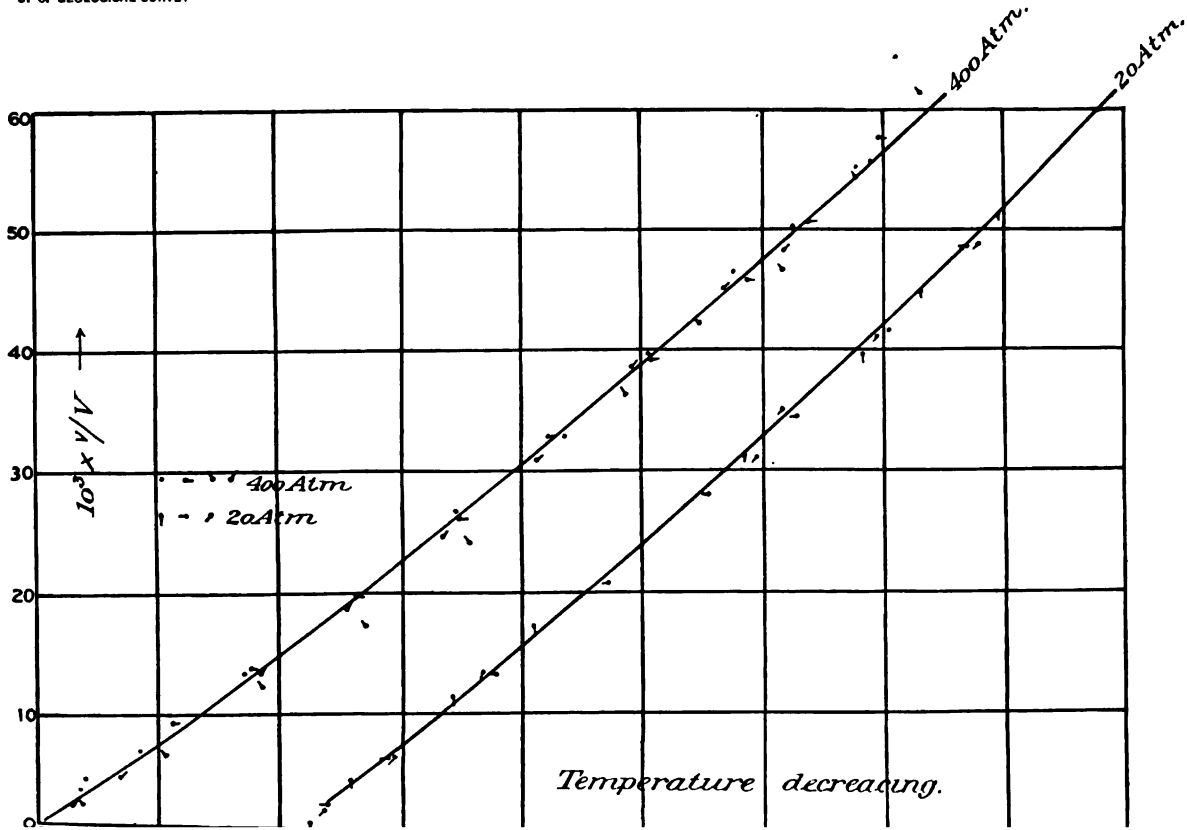
TABLE 54.—*Effect of compression on the resistance of mercury, and of zinc sulphate solution.*

[Cailletet tubes: Internal diameter, $0{\cdot}08^{cm}$; external diameter, $0{\cdot}90^{cm}$.]

Commercial mercury.				Concentrated solution, sulphate zinc.			
δp.	$10^3 \times \delta R/R$.	$10^3 \times \delta r/r$.	$10^3 \times \delta R_0/R_0$.	δp.	$10^3 \times \delta R/R$.	$10^3 \times \delta r/r$.	$10^3 \times \delta R_0/R_0$.
Atm.				*Atm.*			
25	—1·1	—0·1	—1·0	(1) 40	—2·7	—0·2	—2·5
50	—2·2	—0·2	—2·0	70	—4·0	—0·3	—3·7
75	—3·2	—0·3	—2·9	.....	.....	.....	.....
100	—4·3	—0·4	—3·9	(2) 50	—2·5	—0·2	—2·3
125	—5·5	—0·5	—5·0	.....	.....	.....	.....

It can not be said that the effect of gaseous polarization in case of zinc sulphate is thus eliminated. I was not surprised, therefore, to find these results less regular than in case of mercury. In the mean of two series of measurements with pressure increasing and pressure decreasing, respectively, the thermal effect of compression may be considered

Digitized by Google



Digitized by Google

Digitized by Google

eliminated, provided the observer waits long enough between series and observations. During these intervals of waiting the assistant easily keeps the pressure constant by moving the screw injector of the Cailletet pump.

55. *Correction for volume changes of tube.*—Allowance may be made for the volume changes of the tube as follows: If r be the resistance, σ the specific resistance of a column of length l, section q and volume v, then

$$r=\sigma l/q=\sigma l^2/v;\ \delta r/r=2\delta l/l-\delta v/v \quad \cdots \quad (1)$$

In case of internal pressure and a long cylindrical tube[1]

$$\delta v/v=p\frac{\rho_1^2}{\rho_2^2-\rho_1^2}\left(\frac{1}{k}+\frac{\rho_2^2}{\rho_1^2}\frac{1}{n}\right) \quad \cdots \quad (2)$$

where p is the hydrostatic pressure applied, ρ_1 and ρ_2 the radii internal and external of the tube, $1/k$ the compressibility, n the rigidity of the glass. Again, nearly enough,

$$\delta l/l=\frac{\rho_1^2}{\rho_2^2-\rho_1^2}p\mu \quad \cdots \quad (3)$$

where μ is Young's modulus. Hence

$$\delta r/r=p\frac{\rho_1^2}{\rho_2^2-\rho_1^2}\left\{\frac{2}{\mu}-\frac{1}{k}-\frac{\rho_2^2}{\rho_1^2}\frac{1}{n}\right\} \quad \cdots \quad (4)$$

in which equation, in case of capillary tubes, the last term is alone of interest. Everett's (loc. cit.) values for flint glass, this being the substance of my tubes, are

$$k=4{\cdot}1\times10^{11};\ n=2{\cdot}4\times10^{11}\quad \mu=6{\cdot}0\times10^{11}\text{ atm.}=10^6.$$

Introducing these into equation (4), the values $\delta r/r$ given in Table 54 follow.

In addition to the gauge inaccuracies, the resistance of the mercury column of the Cailletet tube is too small for fine measurements. The galvanometer deflection is more or less fluctuating. Hence I have rounded off the data in Table 54. The resistance of the zinc sulphate column in such a tube is about 20,000 ohms. Having no sufficiently sensitive telephone or dynamometer, I made galvanometer measurements, though these are less well adapted for electrolytic work. Other technical difficulties are to be passed over here.

56. *Preliminary result stated.*—The interesting result of table 54 is this: Both in the case of mercury (metal) and of zinc sulphate solution (electrolyte), the electrical effect of compression without change of temperature is a decrement of specific resistance, proportional to pressure. Relatively speaking the order of this decrement in the two

[1] Tait, loc. cit.

Digitized by Google

cases is not very different, being less than one-half per cent per 100 atmospheres. The greater coefficient found for zinc sulphate may be too large, because of the condensation of the polarization gases during compression.

PIEZOMETER METHODS AND RESULTS.

57. *Tubular piezometer described.*—After these encouraging results I resolved to repeat the mercury experiment with greater accuracy. I availed myself for this purpose ot a change of method, by which much greater pressure could be applied to filamentary capillary tubes, similtaneously within and without. The apparatus used is practically a tubular piezometer of steel, the dimensions of which are necessarily slender. Filamentary tubes and metallic vessels insure greater constancy of temperature. In a thick glass tube the temperature of the mercury thread can not be certainly known.

The piezometer is shown in Pl. XXVI. Here *ddd* · · · is the steel tube screwed below into a flange *FF*, by which it is attached to the Cailletet pump. Cf. § 5. The mercury to be compressed is contained in a glass tube *acfk*, the lower part *cf* of which is drawn out into a very fine capillary. The lower end communicates with another glass tube *f*, carrying a platinum capillary tube bent hook-shaped, *k*. Above, the platinum wire *ac* (one electrode) has been inserted into the wide part *a* of the tube and extends down as far as *c*, where it is in contact with the mercury. The top is closed with a thread of marine glue, which secures the platinum wire in place. To introduce the mercury into the capillary tube *ack*, it is withdrawn from the apparatus and filled in a suitable way by aid of a mercury air pump. A layer of marine glue *gg* holds the tube in place. The perforated screw *b*, through which the platinum wire *a* passes without contact, closes the tube. Leakage is prevented by putting in *b*, when hot, and dipping it in liquid marine glue before inserting. After these adjustments are made the steel tube *ddd* · · is inverted and mercury *hhh* · · · poured in from below. A prolongation *ee*, ending below in a hook, is screwed to *ddd* · · ·, so that when the tube is in position again it remains filled with mercury. The air pump may also be carefully used to make this filling. To facilitate the adjustment various other appliances are necessary. I omit them here, as they easily suggest themselves to the physicist. Electric current enters on the outside of the iron trough, § 5, and passes via *h* into *k* and the mercury *i*; thence through the capillary mercury thread *cf*. and the platinum wire *ca* back to the battery.

Let me add that the end *a* of the tube *ack* is much stronger and of finer bore than has been shown in the figure. It will be noticed that *fk* is a reservoir, permitting contractions of the inclosed mercury during compression. When different low temperatures are necessary for observations, the whole length of steel tube *ddd* · · · is to be jacketed with an appropriate thermal bath.

Digitized by Google

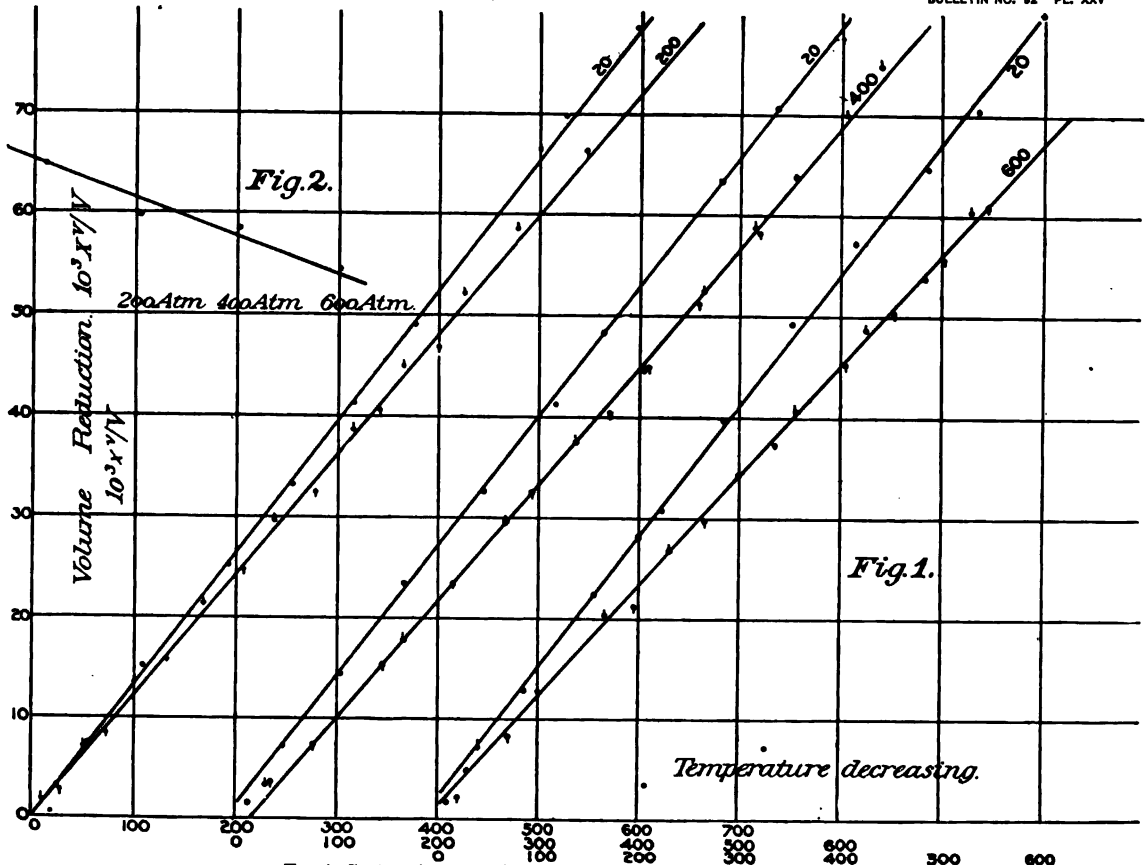


FIG. 1. Contraction on cooling under pressure. Monochloracetic acid.
FIG. 2. Relative rates of contraction. Monochloracetic acid.

Digitized by Google

Digitized by Google

Results.—Most of the data of Table 55 were obtained at about 20°. ıse of the work detailed in the last column, however, I surrounded ube with a cold-water jacket, in this way guarding against thermal s. p denotes the hydrostatic pressure, $\delta R_0/R_0$ the corresponding cted decrement of resistance. Correction is easy in this case, beimply p/n, where n is the rigidity of the glass. The table also R, the resistance in ohms of the divers mercury threads whose)ximate length is l and mean radius ρ_1. The mean external diame- the filamentary tubes is ρ_2. Experiments (1) and (4) were made the same glass tube differently adjusted. Experiments (5), (6), 3) with two other tubes. The last three experiments are the most lete of the series, pressure having been increased from zero to the num (300 to 500 atmospheres), and then again decreased from the num to zero. The mean of these pairs of data appears in the

Again, (6) is obtained with a small Bourdon gauge (0 to 300 pheres, cf. § 9), (7) and (8) with a large Bourdon gauge (0 to atmospheres). Hence the agreement of data (6), (7), (8), is an ent check on the gauges used, as well as a warrant for the validity results. This appears clearly in Pl. XXVII, thus substantiating ı remarks made in Chapter I, § 9.

55.—*Effect of isothermal compression on the electric resistance of mercury. Piezometer method.*

$10^8\times\delta R_0\ R$	$10^8\times\delta R_0/R$	$10^8\times\delta R_0/R$	$10^8\times\delta R_0/R$	δp	$10^8\times\delta R_0\ R$	$10^8\times\delta R_0\ R$	$10^8\times\delta R_0/R$	$10^8\times\delta R_0/R$
*(1)	(2)	(3)	(4)	*Atm.*	(5)	(6)	(7)	†(8)
—0·63	—0·49	—0·37	—0·58	25....	—0.92	—0·79	— 0·76	.....
—1·50	—1·29	—1·22	—1·37	50....	—1·69	—1·56	.....	1·44
Break.	—2·03	—1·95	—2·13	75....	—2·47	—2·31	— 2·19	.....
.....	—2·75	—2·69	—2·89	100....	—3·24	—3·10	.....	3·02
.....	—3.47	—3·41	—3·61	125....	—4·01	—3·75	— 3·82	.....
.....	Break.	—4·11	—4·38	150....	—4.71	—4·57	.....	4·42
.....	.....	—4·84	Break.	175....	Break.	—5·31	— 5·35	.....
.....	.....	—5·15	.....	200....	.....	—6.07	.....	5.91
.....	.....	—6·21	.....	225....	.....	—6·87	— 6·77	.....
.....	.....	—7·09	.....	250....	.....	—7·50	.....	7·43
.....	.....	—7·67	.....	275....	.....	—8·28	— 8.22	.....
.....	.....	—8·20	.....	300....	.....	.....	.....	8·96
.....	.....	Break.	.....	325....	.....	.....	— 9·73	.....
				350....	.....	.....	.....	10·41
				375....	.....	.....	—10·81	.....
18ω	18ω	18ω	18ω	$R=$	10ω	7·5ω	7·5ω	
15cm	15cm	15cm	15cm	$l=$	15cm	15cm	15cm	
·005cm	·005cm	·005cm	·005cm	$\rho_1=$	·007cm	·008cm	·008cm	
·03cm	·03cm	·03cm	·03cm	$\rho_2=$	·035cm	·035cm	·035cm	

* temperature, series (1) to series (7) is 18°.
† temperature, series (8), is 6°. At $\delta p=350$ atmospheres no change of resistance was obıring 6 minutes of waiting.

. XXVII, all these data are constructed graphically. The divers f observations are numbered as in Table 55, and together they p a diagonal line running quite across the chart. It is seen e distribution of points differs quite as much for one and the ıbe ((3), (2), (4), (1)), as it does for different tubes ((1) to (4), o (8)). As a rule the deviations are errors largely avoidable. nit a discussion, and merely refer to the good agreement of the ies (6) to (8) already mentioned.

Digitized by Google

DEDUCTIONS.

58. *Purely thermal variation of resistance.*—Accepting Grassi's[1] value for the compressibility of mercury, 3×10^{-6} per atmosphere, which is a fair mean of the data of Colladon and Sturm, and of Oersted, the chart easily enables me to pass from $\delta R/R$ as a function[2] of p, to $\delta R/R$ as a function of $\delta v/v$, where v is the symbol of volume. Again from the known electrical temperature coefficient[3] of mercury (0·0008 at ordinary temperatures), and the known coefficient of expansion (0·00018), it is easy to construct $\delta R'/R'$ as a function of $\delta v/v$, when the cause of the simultaneous variation is change of temperature. Hence the chart contains two lines, showing the values of $\delta R/R$ corresponding to the same volume decrement $\delta v/v$, when the causes of variation are temperature alone, and pressure alone, respectively. Curiously enough, $-\delta R/R>\delta R'/R'$, an important result, which I shall presently interpret. The chart also contains the corresponding data for solution of zinc sulphate. $\delta R/R$ is in the region of negative δR; $\delta R'/R'$, however, in the region of positive δR. Numerically $\delta R'/R'$ is very large in comparison with $\delta R/R$, besides having the opposite sign.

The line extending through the chart is very nearly straight. Compatibly with the accuracy of measurement it may, therefore, be inferred that the ratio of the quantity $\delta R/R$ to $\delta v/v$, or to pressure, is constant throughout an interval of about 500 atmospheres. Hence the conclusions, § 56, drawn from Table 54, are materially substantiated by Table 55. The chart expresses approximate relations which may be put succinctly as follows:

By subjecting commercial mercury to pressures between 10 and 400 atmospheres isothermally, $-\delta R/R=30\times10^{-6}\,\delta p$, where $\delta R/R$ is the decrement of specific electrical resistance R, corresponding to the pressure increment δp. If v be the symbol of volume, then $\delta v/v=3\times10^{-6}\,\delta p$. Hence $\delta R/R=10\delta v/v$.

If θ be the symbol of temperature, the results which apply isopiestically at ordinary temperatures and pressures are $\delta R'/R'=800\times10^{-6}\,\delta v$; $\delta v/v=180\times10^{-6}\,\delta\theta$. Hence $\delta R'/R'=4{\cdot}4\,\delta v/v$, where R' refers to electrical resistance considered in its thermal relations.

59. Again, by subjecting a concentrated solution of zinc sulphate to pressures between 10 and 150 atmospheres, isothermally, $-\delta R/R=50\times10^{-6}\,\delta p$. The other relations corresponding to the above must be estimated:

$$-\delta v/v=50\times10^{-6}\,\delta p;\quad -\delta R'/R'=0{\cdot}4\,\delta\theta;\text{ and }\delta v/v=200\,\delta\theta.$$

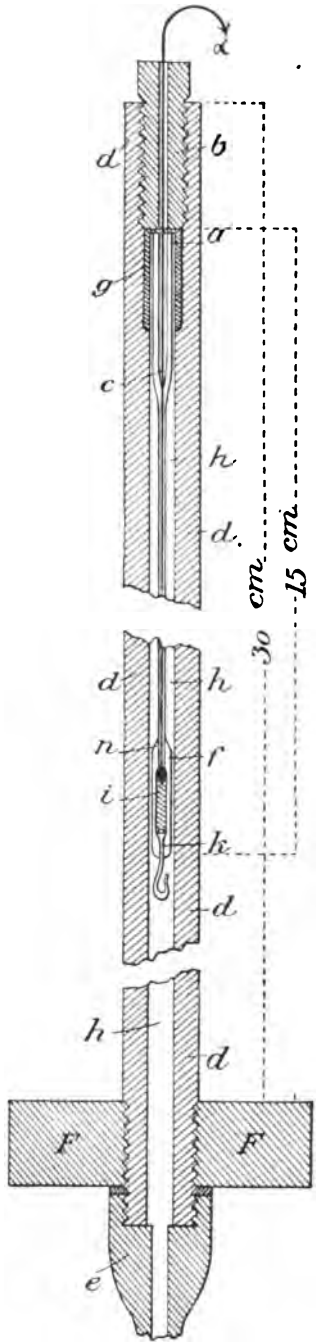
The chief magnitudes are here of different order and even of sign from

[1] The newer values of Tait and of Amagat (loc. cit.) would not essentially modify the statements of the text.

[2] The subscripts zero, which were used above to accentuate the corrected values of R etc., are henceforth conveniently dropped.

[3] I made a special measurement of this coefficient for the mercury used.

Digitized by Google



Apparatus for compressing mercury.

Digitized by Google

Digitized by Google

e applying to mercury. Therefore, this estimate is sufficient for the wing inferences:

ıe chart shows at once that to bring the compression loci into coinci-'e with the thermal loci, the former must be rotated around the ı in a direction contrary to the hands of a watch. The angle of :ion is much greater for zinc sulphate solution than it is for mercury. :e, as before, both in the case of the metal and of the electrolyte, effect of isothermal compression is a decrement of resistance pro-onal to pressure, and by deduction, *the immediate electrical effect se of temperature, $\delta R'/R' - \delta R/R$, is a decrement of specific resist-both in the case of the metal* (Hg), *and of the electrolyte* ($ZnSO_4$+Aq). iis points out an inherent similarity between the metallic and lectrolytic conduction.

Comparison with J. J. Thomson's equation.—In J. J. Thomson's[1] ·ssion for specific resistance $R = \sigma = (2\pi\beta/K)(q/mx)$, suppose, to fix ideas, that β, K, and q are constant, whereas, m, the number of :ules splitting up per unit of volume, per unit of time, and x, the nce passed over by the partial molecule moving at a mean velocity ring the interval of freedom t, are regarded as variable. Clearly x ot be independent of m. Taking active molecules alone into con-ıtion, supposing them to be symmetrically distributed and to move lel to each other, $x = \sqrt[3]{1/mt}$. Hence

$$R = (2\pi\beta q/K)x^3/c.$$

s is in accord with the above data. Reduction of volume $\delta v/v$, ·rmally by pressure diminishes x only. Reduction of volume stically, by cooling, diminishes both x and c. Hence the greater ution of R in the former instance (pressure). Finally, by partial ntiation under the given conditions $dR/dm = -(4\pi\beta q/3K)^3\sqrt{t/m^5}$. this it may be conjectured (conjectured because t and m are not ·ndent of each other) that the effect of R on an additional num-molecules splitting up, decreases rapidly with the total number tting up; i. e., that the numeric of the immediate electrical effect ıperature, $\delta R'/R - \delta R/R$, is smaller for the metal than for the ılyte. This also is in accord with the above data.

Zero of resistance.—In connection with these results it is well to ı passing, that, supposing the laws to hold indefinitely, the zero stance would be reached only after compressing mercury with a f 33,000 atmospheres; but that it would be reached considera-'ore the zero of volume.

Electrical pressure measurement.—It follows, furthermore, from ıve measurements, that the variation of the resistance of mercury ciently marked, and bears a sufficiently simple relation to the ıcumbent pressure, to suggest the use of this principle for ·e measurement.

[1] J. J. Thomson: Application of dynamics, etc., London, Macmillan, 1888, p. 299.

Digitized by Google

63. *Measurement of melting point and pressure.*—Curiously enough the results of Lenz (loc. cit.) for mercury are much larger than mine. Working between 0 and 60 atmospheres, and upon pure mercury filled into a piezometer tube by Weinhold's vacuum apparatus, Lenz found a resistance decrement of ·02% per atmosphere at zero degree centigrade. This is considerably larger than my result, ·003% per atmosphere, at 18°. It is impossible to detect the cause of the difference. Lenz's work was done in a way which from the description accessible to me is faultlessly precise, and my own experiments were so frequently repeated that I can not believe them in error. Possibly slight changes of composition may effect a large difference of compressibility, and my mercury was not quite pure. It is useless to speculate on the causes of difference here. They are now of secondary interest. This part of the work can easily be perfected in any measure. The point of importance at present follows more emphatically from Lenz's large datum than from my smaller result. It is clear that in the usual course of my work I may anticipate electrical variations of resistance due to pressure to the extent of several per cent; but a resistance decrement, $\delta R/R$, of this value, whenever methods of differential comparison are available, is virtually a very large quantity, capable of being followed with great accuracy. It is interesting to note, moreover, that the numerical value of $\delta R/R$ in question is over ten times as large as the corresponding volume decrement, $\delta v/v$, and that the elastic or dimensional discrepancy is even in most unfavorable cases not above 10% of the total decrement.

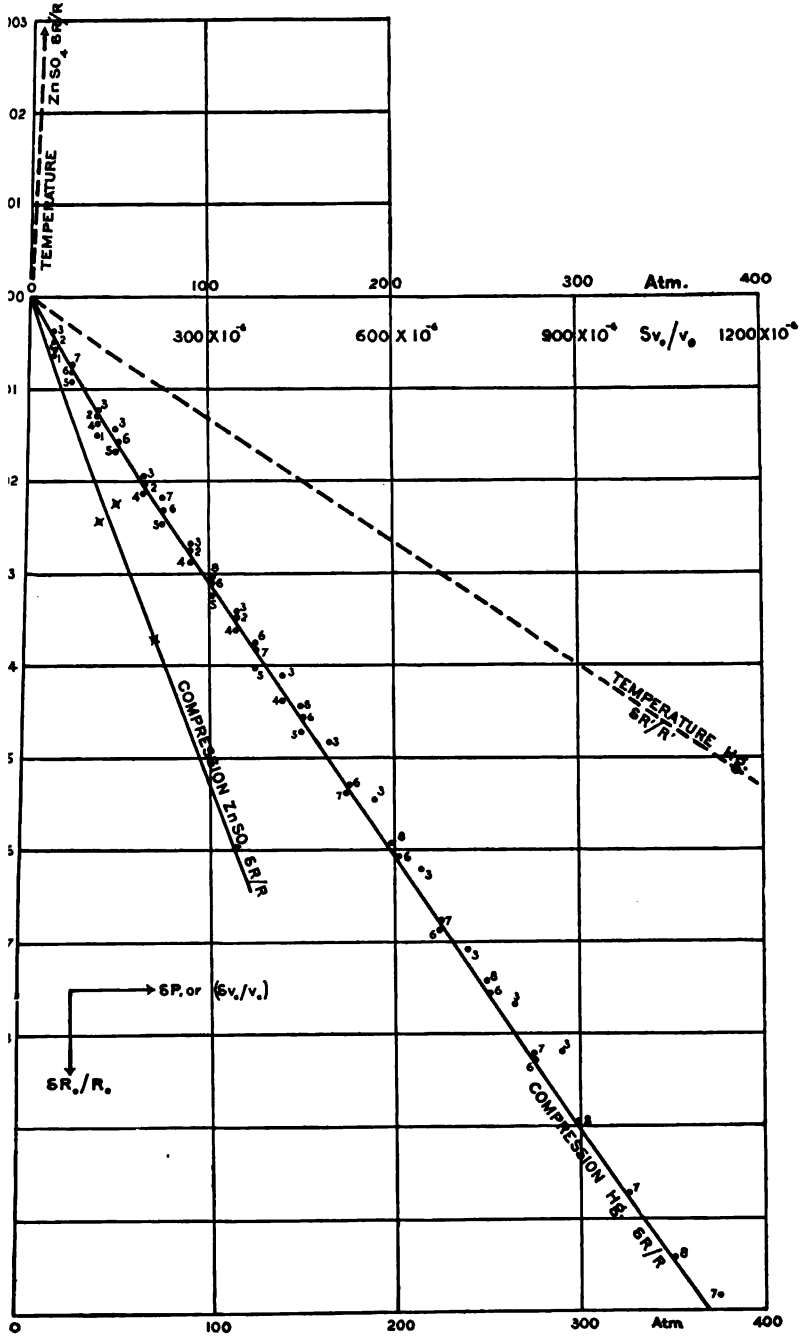
Hence I may confidently infer that the method sketched in the present chapter is sufficiently sensitive to throw much light on experimental questions relative to the continuity of the solid and liquid states. Prof. J. Willard Gibbs (loc. cit.), by constructing entropy energy and volume in the direction of three rectangular axes, has devised exceedingly beautiful geometric methods for the general study of continuous changes of physical state. Prof. Poynting[1] has discussed the subject with especial reference to the transition solid-liquid. Among others Amagat (loc. cit.) is searching for the lower critical temperature. Apart from these suggestive contributions, our knowledge of what actually takes place in liquid matter is meager in the extreme. Hence any general method capable of elucidating the unknown topography of the thermodynamic surface of liquids deserves most painstaking scrutiny. The advantage of the above resistance method over the ordinary optic and other similar methods lies in the fact that in the above case the *character* of the fusion is described step by step. This is a much broader criterion than a merely arbitrary fusion test.[2]

64. *Conclusion.*—In conclusion I may advert to the fact that a study of fusion phenomena in the manner indicated is destined to throw much

[1] Poynting: Phil. Mag. (5), vol. 12, 1881, p. 32.

[2] Another available method for describing the degree of fusion is given by the volume changes at the melting point. Both of these I hope at an early date to apply.

Digitized by Google



showing the relations between corresponding values of the increments of specific resistance, rostatic pressure, and volume compression in case of mercury and a concentrated solution of sulphate.

Digitized by Google

Digitized by Google

t on obscure points in physical chemistry. The molecular mechan-
through which energy is potentialized during fusion can not on the
s of any atomistic theory even be rationally conjectured. Retarded
lification, supersaturation, and allied phenomena point to occur-
es at the melting point the signification of which is much under-
nated. Recent minute researches into the nature of solution should
blind us to the fact that questions which apparently lie much
er home, viz, the underlying molecular causes of change of phys-
state of aggregation, are as yet unsatisfactorily fathomed.

Digitized by Google

CHAPTER III.

THE COMPRESSIBILITY OF WATER ABOVE 100° AND ITS SOLVENT ACTION ON GLASS.

INTRODUCTION.

65. *Behavior of water.*—When temperature rises the compressibility of water continually decreases until about 60° is reached. After this temperature increasing further, the compressibility of water increases. It was my original purpose to supplement these results by determining the compressibility of water between 100° and 310°, but I did not get higher than 185°. At this temperature, and obviously much below it, water attacks ordinary glass so rapidly as to make the measurements in glass tubes worthless.

66. *Literature—Compressibility of water.*—The peculiar behavior in question has attracted many physicists. Grassi[1] was the first to find that the compressibility (β) of water decreases with temperature, being $50/10^6$ at 0° and $44/10^6$ at 53°. He also observed the compressibility of solutions to be less than that of water. Amaury and Descamps[2] substantiate the latter result, but they only observe at a single temperature, 15°, at which $\beta = 46/10^6$. In Cailletet's[3] experiments, extended as far as 700 atmospheres, only a single temperature is given ($\beta = 45/10^6$), and the same is true of Buchanan's[4] results. After this the subject was vigorously attacked by Tait[5] and his pupils, at first particularly with reference to the depression of the temperature of maximum density of water[6] produced by pressure. In further experiments Tait[7] studies the thermal relations of the compressibility of water. Further results are due to Pagliani and Palazzo,[8] working with mixtures of water and alcohol, but more directly to Pagliani and Vicentini.[9] The last ob-

[1] Grassi: Ann. de ch. et de phys. (3), vol. 31, 1851, p. 437. Cf. Wertheim: Ann. ch. et phys. (3), vol. 23, 1848, p. 434.

[2] Amaury and Descamps: C. R., vol. 68, 1869, p. 1564.

[3] Cailletet: C. R., vol. 75, 1872, p. 77.

[4] Buchanan: Nature, vol. 17, 1878, p. 439.

[5] Tait: Proc. Roy. Soc. Ed., vol. 11, 1881, p. 204. Marshall, Smith, and Omond: Ibid., vol. 11, 1882, pp. 626, 809. Tait: Ibid., p. 813; ibid., vol. 12, 1882–'83, p. 226; ibid., vol. 13, 1884–'85, p. 2.

[6] The probability of such an occurrence had been inferred by Puschl and by Van der Waals (cf. Grimaldi, loc. cit.

[7] Tait: Proc. Roy. Soc. Edinb., vol. 12, 1882–'83, p. 45; ibid., p. 223; ibid., 1883–'84, p. 757.

[8] Pagliani and Palazzo: Beiblätter, vol. 8, 1884, p. 795.

[9] Pagliani and Vicentini: Beiblätter, vol. 8, 1884, pp. 270, 794; Journal d. Phys. (2), vol. 30, 1883, p. 457

Digitized by Google

servers corroborate Grassi's work, and find that water shows a minimum compressibility at 63°. Grimaldi[1] critically reviews the maximum-density experiments of Puschl, of Van der Waals,[2] of Marshall, Smith and Omond, and of Tait. Amagat,[3] applying a new method of pressure measurement, "à pistons libres," operates with pressures as high as 3,000 atmospheres and at temperatures between 0° and 50°. He shows that the peculiarities of the behavior of water vanish at high pressures and increasing temperatures (interval, 0° to 50°), corroborating Grassi. Tait,[4] in a final paper, summarizes much of his work, and begins a series of experiments showing that the effect of solution is analogous to an increase of internal pressure.

67. *Literature. Solvent action of water.*—From this brief summary it appears that results anticipating the contents of the present paper are not at hand. There is another class of experiments relating to the expansion of water compressed in glass tubes, to which I must advert. The experiments of Waterston[5] are probably the most complete and carried as far as 300°, although for very high temperatures Daubrée's[6] experiments relative to the action of water on hot glass are to be cited.

METHOD OF MEASUREMENT AND RESULTS.

68. *Apparatus.*—The apparatus used in the present work is the arrangement already described, § 5 to 14. Pressures are applied by aid of Cailletet's large pump. The thread of water is inclosed in a capillary tube between two threads of mercury, and the distance apart of the two inner menisci, measured by Grunow's cathetometer. The tube, suitably closed above, is exposed in a vapor bath (boiling tube). At 185° (aniline), the thread of water soon loses its transparency, becoming white and cloudy. This makes the observation difficult. Fortunately the siliceous water is translucent. By placing a very bright screen behind it, the demarkation between water and mercury remains sufficiently sharp for measurement. After the action has continued for some time, say an hour, the column is solid at high pressure (300 atmospheres), though it is probably only partially so at 20 atmospheres. The result is that threads of mercury break off during advance and retrogression of the column. Further measurement is therefore not feasible. Toward the close of the experiment, moreover, the mercury thread advances inclosed by walls of semisolid siliceous water. The thread is, therefore, of smaller diameter, and the measurement correspondingly inaccurate.

In obtaining these data I followed the customary plan of increasing pressure from zero to the maximum, then decreasing it from the maxi-

[1] Grimaldi: Beiblätter. vol. 10, 1886, p. 338.
[2] Cf. Van der Waals: Beiblatter, vol. 1, 1877, p. 511.
[3] Amagat: C. R., vol. 103, 1886, p. 429; ibid., vol. 104, 1887, p. 1159; ibid., vol. 105, 1887, p. 1120.
[4] Tait: Challenger Reports, vol. 2, part 4, 1888.
[5] Waterston; Phil. Mag., (4) vol. 26, 1863, p. 116. Journ. de Phys. 2 (2) vol. 8. 1889, p. 197.
[6] Daubrée: Etudes synthét. de géologie expér., Paris, Dunod edit. 1879, p. 154 et seq.

Digitized by Google

mum to zero, and taking the mean of the volume changes corresponding to a given pressure. When water does not attack glass, the fiducial mark (pressure zero) at the beginning of the series is regained at the end. When water attacks glass there is considerable shifting.

Boiled distilled water was used, and the glass is common lead glass.

69. *Low temperature data.*—In Table 56 I have given some results for low temperature compression of water. The data are not very sharp, owing to the fact that I did not succeed in sealing the thread of water with its end threads of mercury faultlessly. I think I detected motion of the whole system, which, however, is to some extent eliminated by the method of experiment. The results serve a purpose in introducing the subsequent high temperature experiments. At 400 atmospheres the tube broke. L and θ denote the length of the column of water and its temperature. v/V is the observed amount of volume reduction per unit of volume, due to the burden of p. Finally, $\beta=(v/V)(1/p)$ denotes the mean compressibility between $p=0$ and the pressure corresponding. In view of the irregularities, it did not seem worth while to compute compressibility by more rigorous methods, and the last column simply gives the mean value of β.

TABLE 56.—*Compressibility of water at low temperatures.*

L, θ	p	$\frac{v}{V}\times10^3$	$\frac{v}{V}\times10^3$	$\beta\times10^6$	Mean $\beta\times10^6$ 0 to 400 atm.
	atm.				
9·8cm 31°	0	0·0	0·0	.....	.....
	100	5·3	5·2	52	46
	200	9·5	9·7	48	.....
	300	13·4	12·3	43	.....
	400	15·6	16·1	40	.....
9·9cm 64°	0	0·0	0·0	.....	.....
	100	4·3	4·2	42	49
	200	10·4	9·1	49	.....
	300	16·2	12·6	48	.....
	400	22·3	19·2	57	.....
10·1cm 100°	0	0·0	0·0	.....	.....
	100	6·6	6·1	63	56
	200	11·1	11·9	57	.....
	300	15·9	16·4	54	.....
	*400	20·0	19·2	49	.....

* Tube breaks.

These results contain a mere corroboration of the work of earlier observers. The initial compressibility decreases between 28° and 64°, after which it increases to 100°. Cf. § 12.

70. *High temperature data.*—In the next table (57) the first experiments proper of this paper are described. The symbols used are the same as those in § 4, an additional datum, the time, t, of the observations having been added. The first series of data were obtained at 28°, and are similar to those of Table 56. The next 7 series for 185° are new. Unfortunately I did not observe when ebullition commenced, so that the first dates are not available. After closing the experiment, I

Digitized by Google

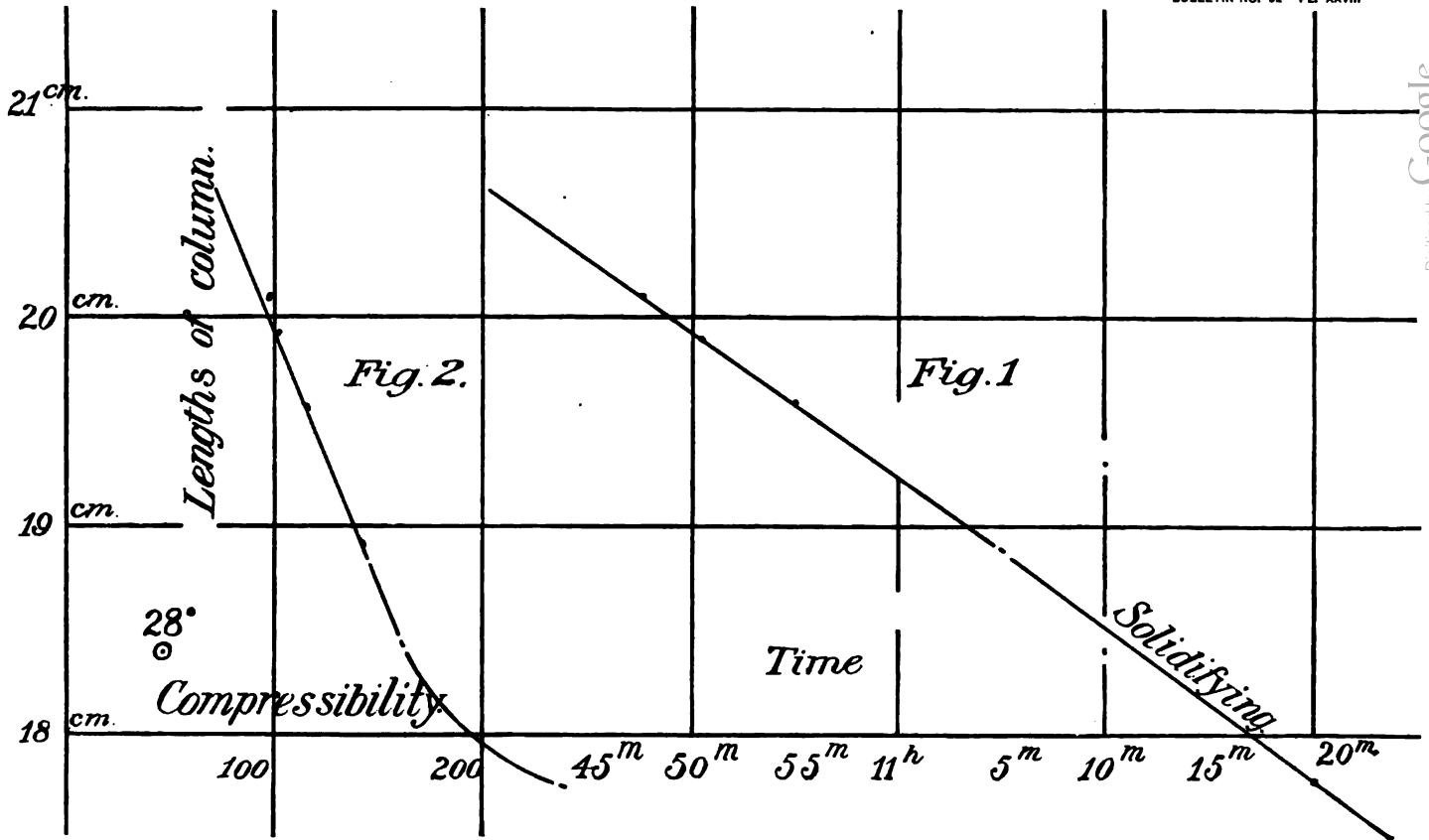


FIG. 1. Time and contraction of superheated silicated water.
FIG. 2. Contraction and compressibility of silicated superheated water.

Digitized by Google

Digitized by Google

noticed that a filament of the upper thread of mercury had run down into the core of the silicated water below it. This means that the action had eroded its way between the mercury and glass. In this respect the observations are uncertain.

TABLE 57.—*Compressibility of water at higher temperatures.*

L, θ, t	p	$\frac{v}{V}\times 10^3$	$\beta\times 10^6$	L, θ, t	p	$\frac{v}{V}\times 10^3$	$\beta\times 10^6$
	atm.				*atm.*		
	20	0·0	.....		20	0·0	.....
	100	3·5	44		100	9·3	116
28°	200	9·4	52	185°	200	21·6	114
18·44^{cm}	300	13·4	48	19·57^{cm}	300	32·7	117
	400	18·5	49		400	42·8	113
	20	0·0	.....		20	0·0	.....
	100	6·7	84		100	11·7	146
185°	200	14·4	80	185°	200	25·9	144
20·45^{cm}	300	21·1	75	18·92^{cm}	300	39·7	142
	400	29·3	77	11^{h} 05^{m}	400	55·5	146
	20	0·0	.....		20	0·0	.....
	100	8·8	109	185°	100	.....	.....
185°	200	17·1	95	18·42^{cm}	200	30·1	167
20·10^{cm}	300	27·4	98	10^{h} 10^{m}	300	44·6	159
	400	34·7	91		400	60·2	158
	20	0·0	.....		20	0·0	.....
	100	8·1	101	185°	100	15·0	188
185°	200	18·3	102	17·78^{cm}	200	31·7	176
19·94^{cm}	300	27·9	100	11^{h} 20^{m}	300	56·2	201
	400	38·3	101		*400	71·8	189

* Solid since threads break off here. Compressibility still increasing.

71. *Discussion of these results.*—To discuss these results I first plotted v/V as a function of p, thus obtaining a series of curves of somewhat irregular contour, the character of which is, however, obvious. This will be more accurately observed (Pl. XXVIII, Fig. 2) by plotting β as a function of the length L of the column, since the time data are imperfect. The result is striking. It shows a mean increment of β of about $50/10^6$ per centimeter of decrement of length of column. Toward the end of the experiment the values of β increase much faster; but here they are uncertain because of solidification. The total observed decrement of L is therefore (20·1–17·8)/20·1, or more than 11%. Since the column at the moment when ebullition started must have been much longer, it follows that the *combined volume* of pure water and solid glass shrinks more than 11%, in virtue of the solution of glass in water up to the point of solidification at 185°. By plotting length L as a function of time (Pl. XXVIII, Fig. 1) the data, though incomplete, show that the volume contraction took place at the rate of 11 per cent per 40 minutes; that is (say), 0·3% per minute. The column therefore soon contracts to a smaller length than the original column at 28°. This is an enormously rapid rate; for were it possible for such action to be indefinitely prolonged the column would be quite swallowed up in 5 hours. Hence it appears improbable that the action of water on glass will be unaccompanied by heat phenomena. (See below, § 74.)

Digitized by Google

72. *High-temperature measurement repeated.*—From the importance of these results I resolved to repeat them with greater precautions. Table 58 contains the results given on the plan of Tables 55 and 56. The first series holds for 24°; the remaining 9 series for 185°. Time is given in minutes, dated from the period when ebullition had fairly commenced. The experiment therefore lasted about one hour. A subsidiary table, 59, contains the essential results (time, temperature θ, volume decrement (v/V), compressibility β) of Table 58. The course of the experiment was very satisfactory.

TABLE 58.—*Compressibility of water.*

θ, L, t	p	$\frac{v}{V}\times10^3$	$\beta\times10^6$	θ, L, t	p	$\frac{v}{V}\times10^3$	$\beta\times10^6$
	Atm.				*Atm.*		
	20	0·0	.....		20	0·0	.....
24°	100	3·6	45	185°	100	11·7	146
13·96ᵐ	200	7·9	44	14·58ᶜᵐ	200	24·9	138
	300	12·2	44	40ᵐ	300	38·9	139
	20	0·0	.....		20	0·0	.....
*185°	100	6·2	77	185°	100	12·9	161
15·42ᶜᵐ	200	14·2	79	14·34ᶜᵐ	200	29·3	163
18ᵐ	300	21·0	75	45ᵐ	300	46·1	165
	20	0·0	.....		20	0·0	.....
185°	100	7·6	95	185°	100	14·7	184
15·17ᶜᵐ	200	17·7	98	14·03ᶜᵐ	200	32·8	182
25ᵐ	300	27·8	99	50ᵐ	300	52·0	186
	20	0·0	.....		20	0·0	.....
185°	100	8·7	109	185°	100	18·3	.....
15·01ᶜᵐ	200	20·6	114	13·75ᶜᵐ	200	39·4	.....
30ᵐ	300	31·9	114	55ᵐ	300	60·5	.....
	20	0·0	.....				
185°	100	9·8	123	185°	Threads broken off; measurement uncertain; siliceous water, solid.		
14·80ᶜᵐ	200	22·9	127	13·56ᶜᵐ			
35ᵐ	300	35·0	125	60ᵐ			

* Commenced boiling at 0ᵐ, say.

TABLE 59.—*Contraction and compressibility of silicated water. Referred to water at 24° and 20 atmospheres.*

θ	$\frac{v}{V}\times10^3$	$\beta\times10^6$	Time.
24°	± 0	44	.....
185°	+103	77	18ᵐ
185°	+ 86	97	25ᵐ
185°	+ 75	112	30ᵐ
185°	+ 60	125	35ᵐ
185°	+ 44	141	40ᵐ
185°	+ 27	163	45ᵐ
185°	+ 07	184	50ᵐ
185°	— 15	221	55ᵐ
185°	— 29	.....	60ᵐ

73. *Discussion of these results.*—The discussion of this table can be made on the lines followed in case of the other (§ 71). Note at the outset that after 55ᵐ have elapsed since exposure to 185° the turbid

Digitized by Google

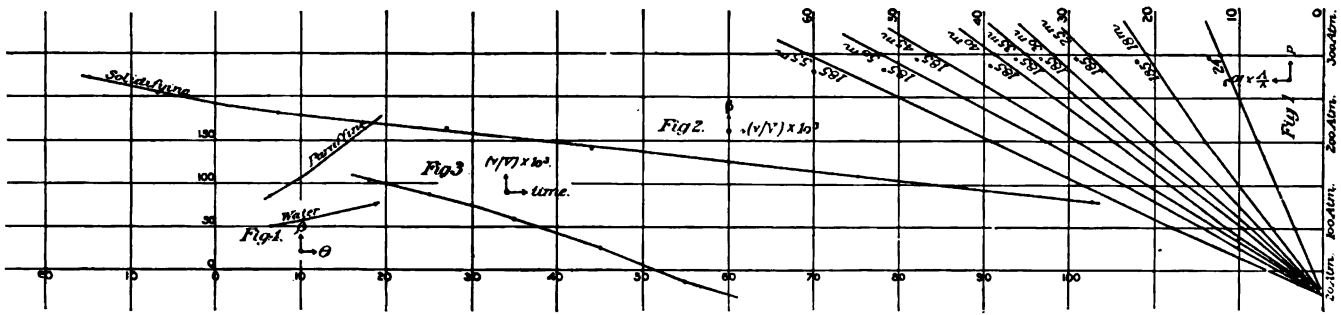


FIG. 1. Successive isothermals of superheated silicated water. 24° and 185°.
FIG. 2. Relation of compressibility and contraction of superheated silicated water.
FIG. 3. Time and contraction of superheated silicated water.
FIG. 4. Compressibility of paraffin and water compared.

Digitized by Google

Digitized by Google

column is not so long as the original cold clear column at 24°. The hot compressibility after 55^m has increased to five times the cold compressibility and more than three times the original hot compressibility. Some allowance must, however, be made for the finer advancing thread of mercury, as explained in § 68. If v/V be plotted as a function of p, a series of curves is obtained as shown in Pl. XXIX, Fig. 1. Considering the difficulties of measurement, they are satisfactorily regular. Temperature and time have been inscribed on each curve. As usual, compressibility decreases with pressure. In Table 59 (v/V) is really the ratio of increment of length to the original length at 24°, due to thermal expansion with concomitant chemical action. It is not the ratio of volumes of solution, because the radius of the tube widens in proportion as solution proceeds. Nevertheless, the datum suffices for the present purposes. Let β be represented in its dependence on (v/V). The plotted curve is a line of remarkable regularity, as shown in Pl. XXIX, Fig. 2. It follows from the chart that β increases $11/10^6$ for each per cent of volume decrease of water undergoing silicification. This is about $75/10^6$ per centimeter of decrement of length, thus agreeing substantially with the former results. Again v/V decreases 13% for the interval of observation of 42 minutes; that is, say, 18% during the whole hour of exposure, or 0·3% per minute, again agreeing with the above result § 71. See Pl. XXIX, Fig. 3.

The regularity of the present results enables me to draw a further inference. Suppose the line for β, v/V to be prolonged as far as $v/V = 150/10^3$, which holds for time = 0. Since in this case the water is pure, the datum for β is the normal compressibility of water at 185°. Making the prolongation (see Pl. XXIX, Fig. 3), I find $\beta = 30/10^6$ nearly. This is, of course, too small a result, and shows that the time at which chemical action began is not well indicated. But since β_{185} can not be greater than $70/10^6$, the compressibility of water above 100° continues to increase at an exceptionally slow rate, about one-fourth as slow as paraffin, for instance (Pl. XXIX, Fig. 4). This indicates exceptional stability of the water molecule.

74. *Conclusion.*—Now what is the underlying cause of this action? Clearly, I think, an instability of the glass molecules at 185°, much rather than any instability of the water molecule. This is in accordance with the evidence I obtained from the study of the electrolytic conduction of stressed glass,[1] and corresponds also to the viscosity of glass at the stated temperature. At 185° the cohesive affinities of the water are sufficient to disintegrate the glass molecule.

The increase of β with time must be due to solution of silicate. Indeed it would be difficult to devise an experiment in which the effect of continued solution can be so well discerned as is possible in the present incidental results. Curiously enough the effect of solution is here an increment of compressibility, whereas in most other cases (cf.

[1] Barus: Am. Journ. Sci., vol. 37, 1889, p. 350,

Digitized by Google

literature, § 66) it is a decrement of compressibility. I leave this without comment, believing, however, that the silicate is in unstable equilibrium with its water when pressure is small, and that the compressibilities measured are solution effects. The possible occurrence of lag here (though I did not search for it) is obscured by the contraction of the silicated column of water. At all events, we have here a case of solidification by pressure from solution, analogous to solidification by pressure from fusion.

Finally, I may advert to the far-reaching geological importance of these results. In so far as the solvent action of hot water is accompanied by a contraction of the original bulk of silicate and water, it is presumably accompanied by the evolution of heat. Hence, if water at a temperature above 200° and under a pressure sufficient to keep it liquid be so circumstanced that the heat produced can not easily escape, the arrangement in question is virtually a furnace; and since such conditions are necessarily met with in the upper layers of the earth's crust, it follows that the observed thermal gradient (i. e., the increase of temperature in depth below the earth's surface) will be steeper than a gradient which would result purely from the normal distribution of terrestrial heat. In other words, the observed rate of increase of temperature with depth is too large, since it contains the effects of a chemical phenomenon superimposed on the pure phenomenon of heat conduction.

Digitized by Google

CHAPTER IV.

THE SOLUTION OF VULCANIZED INDIA RUBBER.

75. In my work[1] on the solubility of glass in water, chapter III, I showed that in proportion as the state of dissociation, or the molecular instability of glass is increased with rise of temperature, the solvent action of water also increases at an enormously rapid rate; that inasmuch as the solution takes place between a solid and a liquid, sufficient pressure must be applied to keep the fluid in the liquid state whenever the vapor tension at the temperature in question exceeds the atmospheric pressure. Thus, at 100° C. the action of liquid water on glass is nearly negligible, whereas at 180° solution occurs at so rapid a rate that the capillary tubes may become filled with solid hydrated silicate in place of water in an hour. Here, however, at least 10 atmospheres must be applied to keep the water in the liquid state essential to speedy reaction.

76. *The present application.*—Having attempted to apply the same principle to the actual solution of vulcanized India rubber I obtained confirmatory results at once. To my knowledge this material has not heretofore been thoroughly dissolved in a volatile reagent, or in any reagent by which it is speedily and copiously taken into solution, and from which it may be speedily and easily obtained. It follows by analogy from § 75 that the rubber must be heated hot enough to be in a state of dissociation, i. e., that the coherence of the solid rubber-sulphur molecule must show an instability in relation to whatever solvent may be used. It follows, moreover, that to facilitate reaction the system of rubber and solvent is to be kept under a pressure sufficient to insure the liquid state of the solvent. It follows obviously that this temperature must not be so high, caet. par., as to change the useful character of the rubber deposited from solution. Hence I act on vulcanized India rubber at the lowest convenient temperature facilitating the solvent action, and at a pressure necessarily exceeding the vapor tension of the solvent at the given temperature. Whatever other favorable action pressure may exert, such, for instance, as forcing the fluid into the physical pores of the rubber by a principle akin to Henry's

[1] Am. Jour. Sci., vol 38, 1889, p. 408. The paper was published in full in the February number of the Am. Jour Sci., 1891.

Digitized by Google

law, is clear gain. In my machine[1] it is rather more convenient to act under 100 or 200 atmospheres than at lower pressures. Hence I did not scruple to use pressures as large as this.

77. *Solution in carbon disulphide.*—I will state here that the samples of vulcanized rubber acted on were five in number and of the character detailed as follows. By elastic I mean stretchable or extensible, with resumption of the original form when the pull ceases:

(*a*) Very elastic sheet rubber, usually non-pigmented and translucent in thin films, brownish in color. Used for rubber bands, for bellows, for chemical rubber tubing, etc.

(*b*) Less elastic and harder rubber, pigmented gray, opaque. Largely used for rubber tubing, sheeting, etc.

(*c*) Non-elastic pigmented rubber, used for low-class rubber tubing and low-class merchandise in general.

(*d*) Ebonite.

(*e*) Same as *a*, rotted by age and exposure.

From experiments made at 100° and 160° C., it appears that elastic sheet rubber (*a*) is not fully soluble in liquid carbon disulphide in a reasonable time, if at all. It is quite soluble at 185° and soluble to a remarkable degree and at a remarkably rapid rate at 210°. Hence the pressure under which solution takes place is here necessarily greater than 15 atmospheres, and need never exceed 30 or 40 atmospheres. Inasmuch as carbon disulphide thus unites with rubber in any proportions clear brown solutions of any degree of viscosity may be obtained. On diluting such solutions with *cold* CS_2 the solvent is at first greedily absorbed, but the final complete dilute solution (without agitation) takes place very slowly. Hence it is well to complete the process for any desirable degree of solution at the high temperature. Finally, by exposing any of the solutions to air the carbon disulphide evaporates and the dissolved vulcanized India rubber is regained without sacrifice of its original non-viscid quality so far as I can judge from laboratory experiments. Similarly fissured sheet rubber (*e*) which has become useless for practical purposes by age, is quite as soluble in CS_2 at 200°, so far at least as the undecomposed parts are concerned. Again, elastic gray rubber (*b*) dissolves completely to a gray liquid in which the pigment is suspended. The concentrated solution hardens at once on exposure to air, to a rubber of nearly the original qualities (*b*). In treating rubbers of this class a difficulty is sometimes

[1] See Proc. Am. Academy, vol. 25, 1890, p. 93, or Phil. Mag., October, 1890, p. 338. My method of work was simple: Glass tubes 10^{cm} or 15^{cm} long and ·3^{cm} or ·4^{cm} in diameter, closed at one end and drawn out to a capillary canal with two or three enlargements at the other, were filled with a charge of vulcanized rubber and solvent, and then introduced into the steel piezometer tube. I made use of the temperatures of boiling turpentine (160°), napthaline (210°), aniline (185°,), and diphenylamine (310°). To separate the charge from the oil of the piezometer which transmits pressure, I first employed a thread of mercury inserted into the capillary canal. Finding, however, § 91, that the metal acted on the charge I replaced it with much advantage by a thread of water. Charges were usually introduced in the ratio of one part, by volume, rubber to three or more of solvent, unless more concentrated solutions were desired. About 1^{cc} to 2^{cc} were obtained per heating. I made considerably over 150 experiments, most of them at 200° and 100 atmospheres to 200 atmospheres.

Digitized by Google

encountered in consequence of their action on the hot CS_2. Gas is often evolved, and I was therefore at first inclined to attribute this effect to the pigments. For example, at 200° such a reaction as $CS_2 + 2ZnO = 2ZnS + CO_2$ might be surmised, but I shall disprove this in §§ 89, 93 by direct tests. Samples of gray non-elastic rubber (*c*) can be partially devulcanized and softened in CS_2 at 200°. They do not easily dissolve, however. Gas is often evolved. Little advantage is gained by treating with CS_2 at 300°, in which case much of the rubber is converted into a granular state, probably due to decomposition.

Commercial ebonite (*d*) at 200° is at first partially devulcanized, and eventually dissolves in excess of the solvent. The partially devulcanized ebonite is elastic on drying, but finally hardens further to a tough solid having a leathery quality. The solution leaves a glossy black stain with much sulphur apparent after evaporating. Gases are usually evolved. As a whole, my experiments show that excess of sulphur is first removed by the solvent, after which the vulcanized rubber itself passes into solution. Cf. § 89, where similar experiments are given.

78. *Solution in liquids of the paraffin series.*—Both the fresh (*a*) and the rotten (*e*) elastic sheet rubber dissolve easily in liquid mineral oils at 200°. The pressure necessary will of course vary with the boiling point of the oil used. It may be as high as 50 atmospheres in some of the very volatile gasolines. Commercial gasoline is a good solvent of the elastic rubbers (*a* and *e*). The most concentrated solutions, however, appear to be less thick than in § 77. On exposure to air gasoline evaporates, leaving a residue which gradually hardens. The gray rubbers (*b* and *c*) dissolve with less facility.

Petroleum[1] dissolves the rubbers *a* and *e* very easily. The solutions, however, only harden after much time, and probably only in thin films.

79. *Solution in turpentine.*—In case of *a*, complete solution is at once effected at 200°, forming a viscid sirup-like liquid. It seems to dry in thin films, after long exposure, thus possibly indicating a difference in the product obtained by dissolving rubber suddenly, out of contact with air, and by dissolving it more or less in contact with air by long-continued digestion. The latter mixtures are permanently sticky. Special experiments made at 160° C. showed that no reasonably speedy solution takes place in liquid turpentine, thus corroborating the inferences and experiments of §§ 75–77. Gray rubber is acted on with greater difficulty. The solution leaves a white glossy stain, which hardens. Pressure need not exceed 5 atmospheres.

80. *Solution in chloroform and carbon tetrachloride.*—Elastic sheet rubber (*a*) dissolves at once in the liquid chloroform at 200°. Pressure

[1] Looking up the literature of the subject, I found that John J. Montgomery, of Fruitland, California (cf. Letters Patent No. 308,189, November, 1884, United States Patent Office), describes a process for the solution of vulcanized rubber. His statements of the temperature and pressure necessary are substantially correct, and he makes use of a petroleum oil boiling at about 200° C. The oil is subsequently driven off by injections of steam. This is the nearest approach to a case of an available solution (a solution which does not remain permanently sticky) which I have found. It will be seen that the essential peculiarity of the above methods is the solution in volatile solvents.

Digitized by Google

must exceed 15 atmospheres and need never be larger than 25 or 30 atmospheres. Solutions of any degree of viscosity seem to be obtainable. They dry at once on exposure to air, leaving a hard residue. Rubber dissolved in this way turns darker in color, and the elasticity is in part sacrificed, so far as I can judge.[1] Gray rubber is attacked with decomposition of the solvent and evolution of gas. Although at 200° a simple reaction like $3ZnO + 2CHCl_3 = 3ZnCl_2 + H_2O + 2C$ might be suspected, I believe the gas to be obtained in the way set forth in § 89.

81. *Solution in aniline.*—Solution in the liquid at 200° takes place at once in case of rubbers like *a*. Pressure need not exceed a few atmospheres. Thin films, apparently dry after long exposure.

82. *Solution in animal oils.*—Neither in the case of sperm oil or of lard oil at 200° was the sample (*a*) dissolved on removing from the press. Both, however, disintegrated on standing to a quasi-solution often with slow evolution of gas.

83. *Treatment with glycerine.*—At 200° no solution occurs. Glycol alcohols were not examined. Cf. § 86.

84. *Solution in benzol and higher aromatic hydrocarbons.*—The elastic sheet rubber (*a*) dissolves at once in the liquid at 200°. Pressure must exceed 7 atmospheres, but need never be higher than 30 atmospheres. The solution exposed to air hardens at once. Solution of gray rubber is more difficult.

Solution of elastic rubber (*a*) in toluol at 200° takes place with great ease. The liquid dries slowly. Pressures of less than 10 atmospheres suffice.

85. *Solution in ethylic and higher ethers.*—Elastic sheet rubber (*a*) dissolves at once in ethylic ether at 200°. Pressure must exceed 25 atmospheres, but need not be greater than 40 or 50 atmospheres. The solution hardens immediately on exposure to air. Gray rubber is attacked with difficulty.

86. *Treatment with alcohols.*—At 200° india rubber (*a*) is not dissolved in methyl or ethyl alcohol, and only slightly so in amyl alcohol. In the latter case the sample shows some change, toward a pasty consistency.

87. *Treatment with ketones.*—India rubber (*a*) treated with acetone at 200° is converted into a sticky paste, from which it hardens at once on exposure to air. Pressure must exceed 15 atmospheres, but need not be greater than 30 or 40 atmospheres.

88. *Treatment with water and mineral acids.*—In no case was there a trace of true solution at 200°. Pressure must exceed 7 atmospheres, but need not be greater than 15 atmospheres. Water probably enters the physical pores of the rubber (*a*); at least this substance becomes superficially rough and warty on drying at 200° in steam after being treated with water at 200°. It does not melt (§ 92). Strong hy-

[1] Such an effect would be produced, for instance, by the presence of sulphur in the chloroform.

Digitized by Google

drochloric acid has no obvious effect, while strong sulphuric acid (diluted with twice its bulk of water) seems only to char the rubber. Treating the gray rubber (*b*) with HCl, I found its solubility in CS_2, C_6H_6, and gasolene to have decreased. The quality of the rubber has therefore been injured, so far as its solubility is concerned.

89. *Treatment for vulcanization.—Liquid ebonite.*—Ammonium polysulphide acting on elastic gray rubber much above 200° converts it externally into a chocolate-like friable skin, covering a mushy gray core. This disintegrates in CS_2 to a brown solution and a gray granular precipitate. The solution hardened on exposure to air, to decomposed rubber.

Ammonium polysulphide at 185° or 200° does not change the appearance of the same rubber markedly; but the sample has lost its elasticity and shows a semiplastic leathery consistency. This I believe to be due to further vulcanization induced by the polysulphide. If now this sample be treated with liquid CS_2 at 200°, the solvent is decomposed with evolution of much gas and the rubber restored to its original elastic quality. It is interesting to note that gas is liberated throughout the mass of rubber, so that the sample when taken out of the tube has the form of an enormously inflated cellular sack, which issues from the glass tube explosively, but soon collapses on exposure to air. As a whole the present results agree with the behavior found for ebonite in § 77. In both cases it is possible to pass from the more vulcanized india rubbers to a less vulcanized product.

It will be shown below that the gas evolved is due to double decomposition of water and CS_2 (§ 93).

More interesting is the direct vulcanization of rubber solution to liquid ebonite by aid of a sulphur solution. In case of elastic rubber (*a*) this begins at 160°, but is more complete at 185° and 200°. In case of *pure* nonvulcanized rubber dissolved in CS_2 scarcely any change in flesh-color is observed at 160° and the sulphur crystallizes out in needles on exposure. At 185° and 200°, however, the charge turns black, showing complete vulcanization. If equal parts of vulcanized rubber (*a*) and sulphur be acted on, the product after heating to 200° is not dissolved nor soluble until the excess of sulphur is removed by washing (§§ 77, 89). Gas is often evolved (§§ 91, 93). In proportion as less sulphur relatively to the rubber is used, the product becomes more soluble and less gas is evolved. By adding about 20 or 25 % of dissolved sulphur to the vulcanized rubber (*a*) I obtained serviceable solutions of ebonite on treating at 200° either in CS_2 alone or in mixtures (§ 90) of this with gasoline or benzol, etc. In most cases these harden very quickly to a jet-black enamel. With less sulphur the color is brown in thin films.

90. *Solution in mixtures of solvents, and solution of mixed gums.*—By acting on vulcanized rubber with mixed solvents of the above kind, I obtained equally satisfactory results. All the rubbers mentioned

Digitized by Google

(*a* to *e*), ebonite excepted, pass into true solutions by aid of such treatment. Thus the gray elastic rubber (*b*) dissolves at once in a mixture of CS_2 and gasoline; and the gray nonelastic rubber (*c*) dissolves with like ease in mixtures of CS_2 with gasoline, or with benzol, or with ether, etc.; or of benzol and toluol; or, less easily, in mixtures of gasoline and benzol. Ebonite is partially devulcanized, and would probably be dissolved in large excess of solvent. No gas was evolved in any case, and this constituted an advantage of this method, § 93. In all cases the solution hardens at once on exposure to air, yielding the rubber if the solution be shaken, or a purer residue if the sediment be removed by subsidence and decantation.

Equally feasible is the solution of mixed gums, at 200°. Thus I made liquid mixtures of vulcanized rubber and gutta-percha in CS_2, which hardended at once on exposure to air; liquid mixtures of rubber and shellac dissolved in CS_2, hardening more slowly; liquid mixtures of vulcanized rubber and rosin in CS_2, and in gasoline, which dried only in thin films after much time, etc.

91. *Direct devulcanization.*—When by aid of any of the above methods a true solution of vulcanized rubber is obtainable, direct devulcanization may be attempted by mixing the charge with some sulphur absorbent. Preferably such material should be chosen, which at 200° reacts neither on the rubber nor the solvent. Metallic filings do not appear to be available at high temperature. Treating ebonite with CS_2, gasoline, or benzol to which copper filings had been added, I found the charge after exposing to 200° to be disintegrated, while an enormous amount of gas was evolved. Scarcely any solvent remained in the liquid tube. From direct experiments made on copper and on sulphur in carbon disulphide at 200°, I inferred that these reactions are insufficient to account for the gas evolved, although copper is superficially coated with sulphide. The gas must, therefore, be produced either at the expense of the rubber or of the reagent in presence of ebonite, and since all the solvents used behave alike, probably out of the rubber. Steel is scarcely attacked[1]. I mention this, since the identification of the gas may throw some clew on the chemical character of the rubber. Decomposition frequently sets in on exposure of a highly vulcanized solution at ordinary room temperatures, whereas at 0° and under slight pressures (1 or 2 atmospheres) the gas remains in combination.

92. *Fusion of impregnated rubber.*—If vulcanized India rubber be impregnated or saturated by digesting it with the cold reagent or solvent for a suitable time (a few minutes to many hours), the swollen mass not only shows a relatively low melting point, but it remains liquid after cooling, provided, of course, the solvent is not allowed to

[1] Fortunately, therefore, steel apparatus is available. An interesting question occurs here, as to what becomes of the carbon in the case where mercury, sodium, copper, etc. are attacked by hot CS_2 under pressure, and not by cold CS_2.

Digitized by Google

escape. This is an observation of practical importance, since the retorts can thus be charged with solid or dry rubber, a minimum of solvent be sacrificed in treating, or by evaporation, and concentrated solutions be obtained often fit to be worked at once. The rubber so melted hardens on exposure to its original quality. Finally, the pressure necessary in this place is the smallest possible, and may be even below the data above given for the divers solvents.

Experiments may be cited as follows: Nonimpregnated vulcanized rubbers (samples *a* to *e*) do not melt if exposed in a closed tube to 210°. Only in a case of very slightly vulcanized pure rubber gum is there a trace of fusion perceptible at the edges, and here it may even be due to a stain of dirt (oil) accidentally deposited there. Gray rubber with a superficial film of exuded sulphur turns black, due to the formation of a film of ebonite.

All the samples of rubber (*a* to *e*) fuse at 210° when previously saturated, or nearly so, with cold carbon disulphide and exposed in a close-fitting closed glass tube. If the pressure be lowered by a capillary hole at one end of the closed glass tube, or if the tube be only partially filled and the empty end kept cool, the solvent is merely distilled off, and no fusion takes place. Whereas at 160° fusion scarcely occurs, melting seems to be complete at 175°. There is, therefore, an approximate coincidence of temperature in the present and in the above paragraphs. Similar results are obtained with benzol, with gasoline, and higher petroleum oils, etc. Fusion is absent or only incipient at 160°, and more than complete at 210°, provided only the solvent used be not too volatile. The gray rubbers (*b*, *c*) fuse to a more viscous or pasty mass than the gum rubbers (*a*), the consistency of the clear cold solution in the latter case being about that of treacle. In general the occurrences of this paragraph resembles the fusion of a salt in its water of crystallization, with this exception, that impregnated vulcanized rubber after fusion retains a consistence which is liquid relatively to the original impregnated charge.

The analogy with starch or gluten solutions is much more perfect. All of these substances swell up when submerged in the solvent. To effect solution or quasi solution, temperature must be raised to below 100° in the former cases, and considerable above 150° in case of rubber. Thus the only real difference in the process is an apparent one; for starch, the solvent water is still a liquid at the solution temperature, whereas for rubber the usual solvents, under atmospheric pressure, are vaporized at the solution temperature. It is interesting to note that a similarly detailed analogy in the thermodynamic behavior of rubber and of soft gelatins has recently been pursued at length by Bjernken[1]. Under sufficient longitudinal stress, both these substances contract on heating, and they are, therefore, heated on further extension, as was proved by Thomson. Bjernken concludes that water

[1] Bjernken.

Digitized by Google

in the gelatins occurs as water and is not in a state of solution or combination.

To account for the behavior of rubber toward solvents, I have supposed coherence to be due to cohesive affinities, forces capable of being saturated like the ordinary chemical affinities, but of smaller intensity and probably greater number. If, therefore, rubber is impregnated with the solvent, a part of the cohesive affinities of the rubber combines with similar affinities of the solvent, and the result is so decided a decrease of the tenacity of the sample that it may now be triturated. If the impregnated material is to be liquid, the residual cohesive affinities of the rubber must be withdrawn from action. This may be done by heat (dissociation). The liquid thus obtained I do not conceive to be a true solution, i. e., one in which the division of solid has reached a definite molecule, but rather consisting of a suspension of excessively small rubber particles in the solvent. Conditions under which this takes place I have already discussed elsewhere[1], and the probable size of the ultimate particles is there indicated. Hence on cooling the solution need not at once become solid again. Diffusion, if occurring at all, is now an excessively slow process. Hence the aggregation of particles takes place gradually, until at length the whole body forms one coherent mass. In other words, all rubber solutions coagulate, and the solid structure in this case is probably that of a network or sponge holding solvent in its interstices.

If the coagulated solution be again heated (under pressure) a thin viscid liquid is again obtained which in its turn coagulates, etc. Hence even if the original rubber be chemically different from the dissolved product (polymerization) my reasoning would hold for the coagulated material.

Finally, I may add that the rubber deposited from any of the above solutions presents a curious case of slowly reacting elasticity. If a thread (say 1^{mm} in diameter) be twisted and then let go on a frictionless surface, it will squirm like a live worm for some minutes after. If it be stretched, the original length is regained with visible slowness. The internal changes probably take place along lines of very nearly neutral equilibrium.

93. *Behavior of reagents and solvents.*—Owing to the frequent occurrence of gaseous products in the above experiments I made special investigations on the decomposition of the reagents. Benzole and gasoline were found stable at 210°, and often above this temperature, whether mixed with water or with sulphur. Cf. § 95. Carbon disulphide, however, in addition to relatively slight decompositions noted in § 91, is decomposed by sodium and by mercury at 210°, although it remains stable in presence of bright steel or of sulphur. It is also stable in presence of zinc white (rubber pigment) at 210°. Violent double decomposition, however, occurs at this temperature in mixtures of water and CS_2, with the

[1] Barus; Am. Jour., Sci., vol. 37, 1889, pp. 126–128.

Digitized by Google

evolution of much gas, presumably $2H_2S$ and CO_2. Thus it appears that a thread of mercury to shut off the experimental tubes § 76 is generally objectionable, as is also a thread of water in case of CS_2. For this reason, moreover, the absence of gaseous reaction in case of mixed solvents, § 90, is to be attributed to the fact that CS_2 and water are not immediately in contact but separated by layers of benzole or gasoline.

An interesting question is suggested here, as to whether it be possible to express affinity on a scale of temperatures. For instance, let it be required to determine the affinity of a metal for sulphur. At ordinary temperatures not even sodium decomposes carbon disulphide, whereas such decomposition occurs in case of many metals if the temperature be sufficiently high. Hence the temperature at which such decomposition definitely sets in (for copper sooner than for iron, etc.) is to some extent a reciprocal expression of the affinity of the given metal for sulphur, bearing always in mind that the stability of the solid metallic molecule also enters into the consideration. Thus the arbitrary reagent CS_2, in its relations to all the metals to be examined, fulfills a similar purpose to an arbitrary spring balance in measuring gravitational forces. Cf. § 95.

94. *Summary of the results.*—In the above paragraphs I have therefore indicated a method by aid of which vulcanized india rubber of any quality or character whatever, as well as the undecomposed or reclaimable part of rubber waste, may be dissolved or liquefied in a reasonably short time[1], and into solutions of any desirable degree of viscosity or diluteness—into solutions, moreover, from which india rubber may be regained on evaporation of the solvent. I have also indicated methods for passing from dissolved vulcanized rubber toward pure rubber, though I see little use for such a step.

I have elsewhere described divers forms of apparatus by which any of the above operations may be carried out on a large scale. They are of no interest here, but I mention them since it is only from such experiments that a full insight into the quality of the rubber deposited from any given solution may be obtained. Throughout my work the constancy of the dissociation temperature has been a marked feature. Thus, in the case of CS_2, of turpentine, of the vulcanization of dissolved pure rubber, etc., no action took place below 160°. It may be noted that even this temperature is higher than where vulcanization is effected in the dry way, where 110° to 140° are deemed sufficient. Moreover, solution of vulcanized rubber takes place at 185°, quite as easily under 700 atmospheres as under the minimum admissible—say 20 atmospheres.

95. *Presumable conditions regarding the solution of carbon, etc.*—From the above paragraphs I inferred that the difficulty encountered in dissolving carbon is probably attributable to the relatively high dissociation

[1] Practically at once, if the material is not too bulky.

Digitized by Google

temperature of the solid carbon molecule. I made many experiments to test this view, in all of which I failed to obtain solution even at low red heat and 600 atmospheres. My work thus corroborates the negative results of Hannay[1] on the direct solution of carbon. My experiments were made with gasoline, water, chloroform, benzole, and carbon disulphide, usually at 500° and 500 atmospheres. In case of gasoline I went as far as low red heat and 600 atmospheres. In most cases the reagents were decomposed (particularly carbon disulphide, benzole, chloroform) to gaseous products, while the carbon remained unaltered. Decomposition by metals if they yielded carbon (copper corroded by CS_2 and gasoline acted on by palladium) showed sooty deposits only. It appears therefore that the dissociation temperature of the amorphous carbon molecule must be looked for in the region of red heat.

In conclusion, I may state that experiments were also made with wood. This material swells up in water, and the inference is, compatibly with the above text, § 92, that if the temperature be sufficiently raised woody tissue must pass into solution. Many tests made upon cellulose in this way showed that the material is decomposed before solution sets in. The phenomena seems to be an ordinary dry distillation in spite of the presence of water under pressure. This is unfortunate, for if it were possible to dissolve wood, our forests would be digestible. At least, any such successful process must contribute essentially to the food products of the race.

[1] Hannay: Proc. Roy. Soc., vol. 30, 1880, p. 188; Chem. News, vol. 41, 1880, p. 106. Cf. Hannay and Hogarth: Chem. News, vol. 41, 1880, p. 103; Mallet and Hannay: Nature, vol. 22, 1880, p. 192.

Digitized by Google

INDEX.

	Page.
Acids, effect of, on rubber	88
Adiabatics	26
Affinity, measurement of	93
Alcohol, compressibility of	30
Alcohols, effect of, on rubber	88
Aniline dissolves rubber	88
Azobenzol, compressibility of	39
Benzoic acid, compressibility of	35
Benzol dissolves India rubber	88
Bibliography of compressibility	17
Bibliography of heat expansion	19
Bibliography of conduction under pressure	68, 69
Bibliography of compressibility of water	78
Bjernken, thermal behavior of gelatin	91
Brom camphor, compressibility of	38
Cailletet force pump	20
Caprinic acid, compressibility of	35
Carbon, solution of	93
Carbon disulphide dissolves rubber	86
Carbon tetrachloride dissolves rubber	87
Chloracetic acid, compressibility of	41
Chloroform dissolves rubber	87
Compressibility, bibliography of	17
Compressibility, data for	28–41
Compressibility at melting and boiling points	50
Compressibility of water	78, 80, 82
Compression, quadratic constants for	42
Compression, exponential constants for	43
Compression, hyperbolic constants for	61
Compression equations compared	65
Contraction, thermal, under pressure	56
Contraction due to aqueous solution	81, 82
Cooling under pressure	56
Devulcanization	90
Diphenylamine, compressibility of	34
Ebonite, liquid	89
Ebonite, devulcanization of	90
Ether, compressibility of	28, 66
Ethers dissolve rubber	88
Expansion due to heat, bibliography of	19
Exponential constants for compression	43, 44
Exponential constants, mean values for	49
Fitzgerald, work of	20
Force pump of Cailletet	20
Fusion of impregnated rubber	90
Gauges for pressure measurement	23
Gibbs, J. W., work of	20
Glycerine, effects of, on rubber	88
Gums, mixed, solution of	89
Heat evolved in aqueous solution	81, 84
Hyperbolic constants for compression	61
Hyperbolic constants for compression, mean values of	64
India rubber, solution of	85
India rubber dissolved in carbon disulphide	86
India rubber dissolved in turpentine, chloroform, etc	87
India rubber dissolved in petroleum	87
India rubber dissolved in aniline, benzol, toluol, ether, acetone	88
India rubber treated with oils, glycerine, alcohols, acids	88
Isometrics computed	62, 50, 54
Isothermals	26
Isothermals computed	50, 54
Isothermal band	65
Ketones dissolve rubber	88
King, Clarence, aids research	15
Levy, work of	20
Melting point and pressure	76
Mendeleef, expansion formula	62
Mercury, resistance under pressure	70, 73
Montgomery, J. J., discovery of	87
Naphthalene, compressibility of	40
Naphthol, compressibility of	39
Oils, effect of, on rubber	88
Piezometer	20, 72
Pressure, measurement of	23, 75
Pressure binomial	43, 61
Pressure, effect of, on thermal contraction	56
Pressure, effect of, on electric conduction	68
Palmitic acid, compressibility of	32
Paraffin, compressibility of	36
Paraffin oils dissolve rubber	87
Poynting, views of	76
Quadratic constants for compression	42
Ramsay, work of	20
Resistance, purely thermal variation of	74
Rücker expansion formula	62
Solution of carbon	93
Solution of india rubber	85
Solution of rubber, theory of	91

Digitized by Google

	Page.
Solution of glass by water	79, 83
Solution of wood	93
Solvents for rubber, behavior of	92
Solvents, mixed, for rubber	89
Tait's correction for piezometric expansion	25, 71
Thermal expansion	27
Thermal expansion, data for	28–41
Thermal expansion, equation for	55
Thomson, J. J., equation of	75
Thorpe, expansion formula	62
Thymol, compressibility of	37
Toluidine, compressibility of	33
Tubes for measuring compression	21
Turpentine dissolves rubber	87
Vanillin, compressibility of	40
Vapor bath	22
Volume changes of glass tubes	25, 71
Vulcanization	89, 90
Water, compressibility of	82, 80, 78
Wood, solution of	93
Young, work of	20
Zinc sulphate, resistance under pressure	70

Digitized by Google

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 93

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

ME INSECTS OF SPECIAL INTEREST

FROM

FLORISSANT, COLORADO

AND OTHER POINTS IN THE

TERTIARIES OF COLORADO AND UTAH

BY

SAMUEL HUBBARD SCUDDER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
ter of transmittal	9
oduction	11
era and species	12
Neuroptera—Odonata	12
Trichocnemis Selys	12
Trichocnemis aliena	12
Stenogomphus, gen. nov	13
Stenogomphus carletoni	14
Hemiptera—Cicadidæ	15
Cicada Linné	15
Cicada grandiosa	15
Coleoptera—Byrrhidæ	16
Nosotetocus, gen. nov	16
Nosotetocus marcovi	17
Coleoptera—Carabidæ	17
Carabites Heer	17
Carabites exanimus	17
Diptera—Œstridæ	18
Palœstrus, gen. nov	18
Palœstrus oligocenus	19
Diptera—Mycetophilidæ	19
Mycetophætinæ	19
Mycetophætus, gen. nov	20
Mycetophætus intermedius	20
Lepidoptera—Nymphalidæ	20
Libytheinæ	20
Barbarothea, gen. nov	21
Barbarothea florissanti	23
Hymenoptera—Tenthredinidæ	24
Atocus, gen. nov	24
Atocus defessus	25

Digitized by Google

Digitized by Google

ILLUSTRATIONS.

			Page.
e I, Fig.	1.	Stenogomphus carletoni	30
	2.	Trichocnemis aliena	30
	3.	Cicada grandiosa	30
	4.	Carabites exanimus	30
	5.	Atocus defessus	30
; II, Fig.	1.	Palœstrus oligocenus	32
	2, 3.	Nosotetocus marcovi	32
	4.	Palœstrus oligocenus	32
	5, 6.	Mycetophætus intermedius	32
; III, Figs.	1–5.	Barbarothea florissanti	34

Digitized by Google

Digitized by Google

LETTER OF TRANSMITTAL.

UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF FOSSIL INSECTS,
Cambridge, Mass., July 24, 1891.

R : I send herewith a paper upon Tertiary insects for publication bulletin of the Survey. The reasons for forwarding it will be found ie brief introductory remarks.

Very respectfully,

SAMUEL H. SCUDDER,
Paleontologist.

)H. J. W. POWELL,
Director.

Digitized by Google

Digitized by Google

SOME INSECTS OF SPECIAL INTEREST FROM FLORISSANT AND OTHER POINTS IN THE TERTIARIES OF COLORADO AND UTAH.

By SAMUEL H. SCUDDER.

INTRODUCTION.

The following pages describe the characteristics of a few Oligocene insects of different orders which, from some peculiarity, have been thought worthy of special study out of serial course, and which would have long to remain unnoticed if they were to await treatment with their immediate allies. Several, indeed, belong to groups already reported on in my Tertiary Insects and elsewhere, and are really on that account the more worthy of notice, as their relation to those already made known can be discussed. Thus the Trichocnemis is interesting as the representative of a type hitherto known, both in the present and past epochs as exclusively gerontogeic; the Stenogomphus as the first of the Gomphina found fossil in this country; the Cicada not only for its great size, but for its being the first member of its family known from American rocks, and it was remarked in my Tertiary Insects (p. 239) as a singular thing that we should have found none; the butterfly is of exceptional interest as belonging to a waning type which must have flourished remarkably in Oligocene times if the figures drawn from the few known fossil butterflies are to be regarded as having any weight at all. These all belong to groups already elaborated. The two Coleoptera are interesting, one from its suggestion of the need of reexamination of allied European Tertiary forms, the other from its remarkable structure. The two Diptera surprise us by their departure from the modern types to which they are most nearly allied, and the existence of one of them proves that bot-flies awaited the appearance on the globe of their most cherished victims among the ruminants. And finally the Hymenopteron described below, besides its curious alliance to oriental forms, well illustrates how perfectly preserved are the numerous and varied Tenthredinidæ entombed at Florissant, whereas all previously described fossils of this family have been exceedingly imperfect and unsatisfactory.

Digitized by Google

GENERA AND SPECIES.

NEUROPTERA—ODONATA.

TRICHOCNEMIS Selys.

TRICHOCNEMIS ALIENA.

Pl. 1, fig. 2.

Nearly allied to the recent *T. didyma* Selys, but easily distinguished from it by the origin of the subnodal, which arises in the nodus itself, from the number of postcubitals, which is eleven instead of seventeen, and from the color of the pterostigma, which is pallid, heavily margined with blackish brown.

Length, 20 millimeters.

The interest attaching to this species is its close alliance to species found in the East Indies and its belonging to a legion, Platycnemis, which is now found only in the Old World, most of its members, indeed, in the tropics. That it belongs in this legion is plain from the origin of the median and subnodal sectors, the former at a point immediately before the nodus (bending strongly upward at its base), from the elongated and regular quadrilateral, from the short pterostigma which surmounts parts of two cellules, but is only equal in length to one, from the entire absence of supplementary sectors, and from the length, straightness, and simplicity of the lower sector of the triangle, which terminates well beyond the middle of the wing. The entire margin of the wing, the length of the lower sector of the triangle, and the relative brevity of the upper side of the quadrilateral, which is about three-fifths as long as that of the lower side, show that it must be referred to Trichocnemis, and that it falls about midway between the subgenera Hemicnemis and Trichocnemis, having close relation to *H. cyanops* from the Seychelles and *T. didyma* from Thibet and Darjeeling by the points of origin of the median and subnodal sectors.

Of further interest is the fact that the legion is already known in the European tertiaries, one species (a mere fragment and referred here with some doubt) in amber, the other, *Platycnemis icarus*, from the Aquitanian of Rott, and that the latter species is so closely allied to our Florissant form as indubitably to fall in the same genus, so that it should be known henceforth as *Trichocnemis icarus;* here also the subnodal arises from the nodus itself; both the median and subnodal have the same abrupt upward curve at the base, and the form of the quadri-

Digitized by Google

lateral is nearly identical; the number of postcubitals is thirteen. I do not recall any so close relationship between the insects of the Rhenish basin and those of our Oligocene beds.

Florissant, Colorado. One specimen. No. 1660, U. S. Geological Survey.

STENOGOMPHUS (στενὸς, Gomphus, nom. gen.) gen. nov.

Upper side of the triangle a little longer than the interior, scarcely shorter than the exterior, which is bent; both inner and outer triangles subequiangular and subequal, each divided into three or four cells by cross veins uniting at the center; hypertrigonal space without transversals; median space with a single cross nervule, the space itself exceptionally narrow apically, diminishing gradually in width from the middle outward and in no way bent where the lower limb of the inner triangle strikes it; sectors of the arculus arising from the same point and continuing as one stem more than half way to the apex of the median space; three complete rows of cellules, following the triangle as far as below the nodus.

These characters are not combined in any known genus of Gomphoides, to which legion of Gomphina, on account of its aborted membranule, it belongs. From the equality of the two triangles, the length of the upper margin of each, and the exceptional straightness of the postcostal nervure, the upper broad extension of the two triangles gives a peculiar facies to the wing, somewhat as if it were a hind wing, which the empty hypertrigonal space, the three complete series of cellules following the discoidal triangle, and the small number of postcubitals intensify.

It is interesting as being the first discovery of fossil Gomphina in America, and as showing an alliance with the existing New World rather than the Old World types. It seems, on the whole, to be most nearly related to Gomphoides and Progomphus, but differs distinctly from the latter in the origin of the sectors arising from the arculus, from Gomphoides in the free hypertrigonal space, the greater length of the upper side of the triangle, and from both in the straightness of the postcostal vein, and in having three instead of two complete series of cellules beyond the triangle, a character which does not appear to have been found in this legion, but which occurs in Cacus, a subgenus in the neighboring gerontogeic legion Lindenia.[1]

There appear to be some other peculiarities about it which future comparisons may show to have some special interest. In all recent species of the legion I have seen, one of the cross nervules in the space between the nodal and subnodal sectors is heavier than the others and oblique, but is placed at very varying distances beyond the nodus, always, however, separated from it by from one to three cellules; in

[1] See further observations under the species *S. carletoni*.

Digitized by Google

Stenogomphus alone is it in direct continuation of the curved base of the nodal sector, and thus forms an integral part of the system or accessory alliance of heavy veins which depend from and form a part of the nodus. Again, the subnodal nervure in all living Gomphina I have seen does not arise directly from the principal sector, but from a bent cross nervule connecting the principal and median sector, or it may be said to be united to the median sector close to its own base by an oblique transversal, while in Stenogomphus its origin is direct, the connection with the median being not yet gained. Add to this that the sectors arising from the arculus, the principal and the short sectors, not only arise from one point, but seem to be entirely blended for a distance from the arculus nearly equal to the length of the latter, and we find a series of characteristics of no little interest. The last feature seems to be found, but to a less extent, in *Gomphoides bifasciata*, and still less in *G. brevipes*, in both of which, however, the veins do not blend until past the extreme base, while in Stenogomphus they have but a single origin. Besides, the number of postcubitals is exceptionally small, these varying in the entire legion from eight to seventeen, and averaging twelve, though in Gomphoides proper, to which Stenogomphus is most nearly allied, the average is ten; in Stenogomphus there are but seven.

STENOGOMPHUS CARLETONI.

Pl. 1, Fig. 1.

A single fore wing and part of its reverse are all that are known of this dragon fly. The wing is hyaline or very faintly infumated beyond the nodus; the reticulation is testaceous, the principal sector and the main veins above it, with the costal margin, ferruginous, deepening into blackish when bordering the ferrugineo-testaceous pterostigma. This latter is subequal, about four and a half times longer than broad, surmounts less than three unequal cellules, its inner bordering vein subcontinuous with the cross nervule below; twelve antecubitals, seven postcubitals; both triangles subequilateral with crowfoot division into three cells, the upper outer angle of the discoidal triangle perhaps sometimes severed by a cross vein to form a minute fourth cell; outer margin of same triangle slightly bent above, scarcely more than a tenth longer than the upper margin, which in its turn is scarcely more than a tenth longer than the inner margin; of the borders of the inner triangle the lower is the longer, the others subequal.

Length, 39 millimeters; breadth, 8·7 millimeters.

The living species to which this is most nearly allied is unquestionably *Gomphoides stigmata* Say sp., found in Texas. To this conclusion both Baron de Selys and Dr. Hagen, to whom I sent sketches of the neuration, arrived independently, and Baron de Selys kindly pointed out some peculiarities of that species, which, in view of the structure of Stenogomphus, have special interest. One of the two specimens (♂ and ♀)

Digitized by Google

in his possession has the hypertrigonal space free on one fore wing but not on the other; while on another is found, also on one wing but not on the opposite, the beginning of a series of five or six very small pentagonal cellules between the two rows of tetragonal ones following the discoidal triangle. By the kindness of Dr. Hagen, Mr. Uhler, and Mr. Calvert, I am able to report regarding the structure of fifteen other specimens of this species; in all without exception on both wings there are next the triangle first three cellules (as figured in de Selys's Monographie des Gomphines), then two series to a point between the origin of the median nervure and the nodus, increasing to a greater number below the nodus; but in the number of transversals in the hypertrigonal space there is some variation; in all but two specimens the wings are alike on the two sides and show either one or two transversals in this space; but one male has three transversals on the left, two on the right side; and one female one transversal on the left, two on the right. Curiously enough these asymmetrical individuals are from the same lot as those in Baron de Selys's collection, viz, the specimens collected by General (then Captain) Pope on the Pecos river, Texas, in the extreme western part of the State, at the time of the Mexican boundary survey; while all the others but two were collected by Aaron in the extreme southern part of the State, between Laredo, 160 miles inland, on the Rio Grande, and Corpus Christi, on the Gulf coast. The last two are in Mr. Uhler's collection.

Crest of Roan Mountains, Colorado, found by Mr. Carleton E. Davis, of my party, in 1889. One specimen, Nos. 1146 and 1185, U. S. Geological Survey.

HEMIPTERA—CICADIDÆ.

CICADA LINNÉ.

CICADA GRANDIOSA.

Pl. 1, Fig. 3.

A single hind wing, showing the complete neuration, except a fragment of the tip, is all that remains; besides indicating a species of very large size, as large as the largest known American forms in North or Central America, and having also unusual breadth, it differs from them much more than almost any of the genera of Cicadidæ do from each other, and therefore indicates a distinct genus. The neuration in general agrees with that given for Fidicina and Cicada by Distant in the Biologia Centrali-Americana, or for that of an East Indian species of Fidicina by Walker (Cat. Brit. Mus., Homopt., Pl. 1, Fig. 2), but differs from them all in an unusual peculiarity, the great length of the apical cells, the transverse interlocking of the veins occurring much nearer the middle of the wing than usual; moreover, the upper ulnar vein when it forks (just before its union with the lowest radial) does so by

Digitized by Google

throwing off an inferior branch from about the center of the wing, while the upper branch, united to the lowest radial, scarcely diverges from the original path of the main stem; and finally, the lower ulnar, when it has run a little more than half its course parallel and close to the sutura clavi, suddenly bends slightly upward and terminates on the outer margin much nearer to the upper radial vein than to the sutura clavi; no trace of the membrane can be seen beyond the marginal vein; the veins are very delicate and the wing immaculate.

Length of fragment, 25 millimeters; probable length of venation in hind wings, 26·5 millimeters; breadth, 10·5 millimeters; probable expanse of fore wings, 115 millimeters.

This is much larger than any of the tertiary Cicadidæ of Europe, none of which have the hind wing preserved.

Florissant, Colorado. One specimen, No. 1850, U. S. Geological Survey.

COLEOPTERA—BYRRHIDÆ.

NOSOTETOCUS (νόσος, τίκτω) gen. nov.

But a single genus, Nosodendron Latr., has hitherto been recognized in the Nosodendrinæ, a subfamily distinguished from other Byrrhidæ by its prominent head, which is not retracted as in the other subfamilies. In the tertiaries of Colorado, however, and perhaps in those of Europe as well, a genus of Byrrhidæ is found in which the head is as prominent as in Nosodendron, but differs from it very distinctly in the character of the antennæ, which in Nosodendron have a distinct and sharply delimited club formed by the abrupt expansion of the three last joints. In the extinct genus, which from its relation to Nosodendron we call Nosotetocus, the antennæ enlarge with great regularity, no one joint being greatly larger than the preceding, and the apical joints being considerably less than twice as broad as the narrowest joints of the stem. In other respects it agrees very closely with Nosodendron, the form of the head being similar, the antennæ composed of eleven joints, of which the second is longer than the others, and all, excepting perhaps the basal joint, which can not easily be seen, are gently obconic, perhaps depressed. The prothorax is short and the scutellum small. The legs are moderately stout, the tibiæ apparently of similar width throughout.

Three species, differing considerably, are found at Florissant, and it would appear probable from the figures and descriptions of the three species which have been referred to Byrrhus from the European tertiaries that they also belonged here. They all appear to have nonretracted heads, and in the case of one, *B. examinatus* Heyd., the antennæ have the same construction as in Nosotetocus. A reexamination of the specimens is desirable, as it would be interesting to know if Nosotetocus preceded Nosodendron in Europe as well as in America. Only one of our species is described here.

Digitized by Google

NOSOTETOCUS MARCOVI.

Pl. 2, Figs. 2, 3.

Form obovate, about half as long again as broad, the head projecting distinctly beyond the front and breaking the regularity of the form, the curve being emarginate on the anterior sides of the prothorax. The head is comparatively narrow, being scarcely transverse, very regularly rounded and scarcely produced in front. The antennæ are considerably longer than half the width of the body, the apical joint, which is largest and slightly produced at tip, nearly twice as broad as the narrowest part of the stem. The elytra are distinctly though feebly striate and the striæ faintly punctured.

Length, 5·25 millimeters; breadth, 3 millimeters; breadth of head, 1·5 millimeters; length of antennæ, 2 millimeters.

Named for the geologist, Prof. Jules Marcou, of Cambridge.

Florissant, one specimen, No. 110.

COLEOPTERA—CARABIDÆ.

CARABITES HEER.

CARABITES EXANIMUS.

Pl. 1, Fig. 4.

The surface of the elytra is smooth but for the sharp, slender, rather deeply impressed, straight striæ, showing feeble signs of scattered delicate punctures, hardly enlarging the width of the striæ and very obscure. The second stria terminates at the base just as it bends outward opposite the tip of the scutellum, while the third runs into the fourth, and there is no basal stria; the second and fourth are roundly united apically around the tip of the third, and are joined to the united fifth and sixth by a short spur; the first and tenth are united at the very tip of the elytra.

Length of elytron, 9 millimeters; middle width of one, 3 millimeters.

Finding it impossible definitely to place this beetle, which is represented only by the elytra, but these in excellent preservation, I put it temporarily in a magazine genus to indicate its general affinities, for its general aspect is that of a large carabid, which the inferior plica of the outer margin strongly confirms; but there is not a sign of dorsal punctures or foveæ, except a minute puncture at the oblique base of the third stria, and even no ocellate punctures between the ninth and tenth striæ. Of all the tribes possessing such an inferior plica, it seems to agree best with the Pterostichini, but there are here nine perfectly and equally distinct and equidistant striæ besides a tenth marginal stria. The elytra are slender, with a distinct emargination at the tip of the inferior plica and with narrowed base and well-

Digitized by Google

rounded humeri; the first and third striæ are deflected outward at their base by the tolerably large triangular scutellum.

From the lowest beds on the immediate bank of the White River, Utah, about 5 miles from the Colorado line. One specimen, Nos. 624 and 626, U. S. Geological Survey.

DIPTERA—ŒSTRIDÆ.

The Œstridæ of the present day live in their early stages beneath the skin or in the glands or cavities of various Mammalia, hardly any of the terrestrial groups being free from their attacks; they principally pursue, however, the Perissodactyla, Ruminantia, and Rodentia, and of these the ruminants are by far the most subject to them, and particularly the Cervidæ and Bovinæ. Now, neither of these dominant families appears to have existed in Oligocene times, when the insect described below flourished, and they have reached their present differentiation and predominance quite despite the attacks of this insect family which was awaiting their advent into the world. Perhaps Palœstrus sought the Tylopoda of the time as its victims.

PALŒSTRUS (*πάλαι, οἶστρος*) gen. nov.

A genus of Œstridæ remarkable for the very striking course of the fourth longitudinal vein, which finds no counterpart in living Œstridæ so far as I can find. Nor, indeed, can I discover anything of the sort among the calyptrate Muscaria. The only species known is of the largest size, rivaling the largest known living forms, with wings of a rather slender form and immaculate. The costal vein is finely and densely bristled, the costal cell of somewhat unusual width, partly from the rather short auxiliary vein which terminates well before the middle of the wing; the first three longitudinal veins terminate at nearly equidistant intervals in the apical fourth of the wing, the second and third, as normally, with upturned tips; the third longitudinal vein arises from the second at slightly less than a third way from the base; the fourth, instead of running in a straight or gently flexed course, perhaps bent, at the middle transverse vein, is profoundly affected by that vein, which is extremely short and lies about as far beyond, as the origin of the third longitudinal vein before, the tip of the auxiliary vein; in passing toward this middle transverse vein the fourth longitudinal vein runs parallel and near to the straight fifth longitudinal vein as far as the middle of the wing, and then curves strongly upward to strike the transverse vein at a wide angle, is there bent at right angles with itself, and passes in a nearly straight course subparallel to the fifth longitudinal until it meets the hinder transverse vein, when it is again bent, this time upward but at a very broad angle, and reaches the margin just beyond the third longitudinal vein, thus leaving the first posterior cell (barely) open; the anterior basal trans-

Digitized by Google

verse vein is directly opposite the origin of the third longitudinal vein; the posterior, strongly arcuate, is situated a little within it; the fifth longitudinal vein terminates just beyond the hinder transverse vein, not reaching the margin. The legs are not very long, the femora remarkably stout, the tibiæ straight, the tarsi of the same length as the tibiæ.

This genus seems to be most nearly allied to Hypoderma, which is found all over the world and attacks various kinds of cattle, but especially Cervidæ, but the whole course of the fourth longitudinal vein is materially different.[1]

A single species is known, from Florissant.

PALÆSTRUS OLIGOCENUS.

Pl. 2, Figs. 1, 4.

The single imperfect specimen that has been found has been so fully described under the genus that little is left to be said. The remains consist of the rotund thorax, the wings, excepting the membranous hind margin, the hind legs and the middle femora; the tegulæ are obscure, but appear to be normal. The wing is hyaline. The basal joint of the abdomen seems to be represented by a detached piece beside a leg, perhaps a fore leg; if so, it is of great size relatively to the thorax, the hinder margin being broader than the thorax; it is blackish brown like the thorax, with the hind margin lighter. The legs, and especially the femora, are delicately bristled; the tibiæ are scarcely in the least enlarged in the middle, and the tarsi are about two-thirds as stout as the tibiæ.

Length of wing, 16 millimeters; breadth of thorax, 7 millimeters; of base of first abdominal segment, 5·5 millimeters; of apex of same, 8 millimeters; length of hind femora, 4·75 millimeters; tibiæ, 5 millimeters; tarsi, 5 millimeters.

Florissant, Colorado. One specimen, Nos. 13703 and 14086.

DIPTERA—MYCETOPHILIDÆ.

Subfamily MYCETOPHÆTINÆ.

This new group is remarkable for combining in the neuration of the wing characters which are found only in distinct groups among living forms. It may be defined as follows: The vena media arises at the base of the wing from the vena postica, but is apparently also united by a cross vein close to its base with the radius. The transverse median vein elongate, very oblique. The humeral cell very slightly enlarged in the middle. The brachial vein present and very much elongated,

[1] It may be remarked, as a precaution to younger students, that in all the figures of Hypoderma, and, indeed, many other genera in Brauer's Monographie der Oestriden, a single vein is made to do duty for both first and second longitudinal veins.

Digitized by Google

both cubital cells open and elongate. The lower discoidal vein originating in the vena postica, but also connected at its base by a cross vein with the vena media, a cross vein which does not exist in the other groups of Mycetophilidæ. The vena axillaris complete.

This group seems to stand between the Mycetobinæ and Sciophilinæ.

MYCETOPHÆTUS (*μύχης, φοιτάω*) gen. nov.

Wings with the form of those of Sciophila, the auxiliary vein terminating in the margin a little beyond the middle of the wing and a little beyond the base of the brachial vein; the marginal vein extending to or almost to the tip of the wing where the cubital meets it; the fourth posterior cell arises as far back as the inner cubital cell; the third posterior is divided into two, a basal and an apical, the latter as long as the fourth posterior; the axillary is also divided into two, an anterior and a posterior, the former much the narrower and narrowing apically. Legs long and slender, the fore femora considerably longer than the thorax, the tibiæ longer than the femora, both abundantly spinous. Abdomen eight-jointed.

At least one species occurs at Florissant.

MYCETOPHÆTUS INTERMEDIUS.

Pl. 2, Fig. 5.

Head and thorax dark, the abdomen much lighter, the legs nearly or quite as dark throughout as the thorax; wings hyaline, but faintly fuliginous in the upper half, especially beyond the middle. The brachial vein arises shortly beyond the transverse median vein, and in its basal half runs parallel to, and close beside, the cubital, but afterwards diverges a little from it and strikes the margin a little nearer the radius. The second posterior cell is long—nearly as long as the hinder cubital cell and broad from the base. The abdomen is slender and tapering.

Length of body, 7·5 millimeters; wing, 5·5 millimeters; femora, 2 millimeters.

Florissant, Colorado. One specimen, Nos. 5937 and 7391.

LEPIDOPTERA—NYMPHALIDÆ.

Subfamily LIBYTHEINÆ.

In my paper on the fossil butterflies of Florissant, published in the Eighth Annual Report of the U. S. Geological Survey, I described an interesting form under the name of Prolibythea, and called attention to the strangeness of the occurrence, in a fossil state, of a butterfly belonging to the subfamily Libytheinæ. Indeed, it may be acknowledged

Digitized by Google

to be much the most interesting of any of the fossil butterflies yet discovered; for when we recall the fact that among existing butterflies the Libytheinæ are by far the most poverty-stricken subfamily known, the occurrence, among the extremely few (less than twenty) fossil butterflies that have been found in any part of the world, of one belonging to this subfamily has a special significance. The existing members are only about a dozen at the most, and, curiously enough, are scattered at the four quarters of the globe. No other subfamily has anywhere nearly so restricted a representation, the Acræinæ, which perhaps come nearest to them in this respect, numbering at least ten times as many, while the numerical proportion of the Libytheinæ to the total number of known butterflies is not far from 1 to 1,000. How much more significant this is, and how much more clearly it proves the living Libytheinæ to be remnants of a waning type, as I have called them,[1] is shown by the occurrence in the beds of Florissant of still another member of this restricted subfamily, so that the Libytheinæ now form more than 10 per cent of fossil butterflies, instead of one-tenth of one per cent, as among living forms. I am indebted to Mr. S. H. Long, of Florissant, Colorado, for the opportunity of studying the most interesting specimen here described.

As will be seen, it is most nearly related to the fossil species previously found in the same beds, *Prolibythea vagabunda*. It is of precisely the same large size, has the same relatively short palpi, somewhat similar antennæ, a similar but not so marked costal lobe at the extremity of the hind wings, and a neuration agreeing very closely with it; so closely, indeed, that it would be regarded by many as a member of the same genus. It differs strikingly, however, in the greater breadth of the wings and in the structure of the antennæ and palpi, and in most of its points shows closer affinities with the European Libythea than with the African Dichora, instead of the opposite, as in Prolibythea. These and other distinctions seem to be sufficient to warrant its generic separation from previous known fossils, and I accordingly describe it under the following name:

BARBAROTHEA (*βάρβαρος, θέα*) gen. nov.

Antennæ slender, the club so gradually incrassated as to be difficult to determine its origin, composed of about one-fourth of the total number of joints, but little more than one-fourth the length of the whole antenna, and less than twice as broad as the stalk, terminating very abruptly, a single joint, or at most two, being concerned in its apical diminution in size; the whole antenna scarcely more than three-fifths the length of the wing. The apical joint of the palpi not more than three times longer than broad, only a little more than two-thirds the length of the second joint. Fore wings a little more than one-half as

[1] See Butt. N. Engl., i: 759.

Digitized by Google

long again as broad, subtriangular, the costal margin regularly and gently arched; the apical margin produced in the upper half of the wing, roundly and not at all prominently angulated at the tip of the lowest subcostal nervule, the last two superior subcostal nervules originating far apart, the outer at a little more than midway between the tip of the cell and the apex of the wing; the third about midway between the second and fourth. Hind wing of very nearly equal length and breadth, the costal margin as in Prolibythea, but with less pronounced apical lobe, the outer border very regularly arcuate and crenulate, not at all produced in the subcostal region, the lowest median nervure widely distant from the submedian and terminating in a distinct but rounded lobe; cell closed by a transverse vein, which strikes the median barely beyond its last furcation.

Of the pattern of the wings little can be made out, but the under surface of the fore wings would appear to be almost uniformly dark, with no oblique patch depending from the costal margin, excepting such as is indicated by a narrow, very oblique, darker, abbreviated bar just beyond the apex of the cell. The hind wing would appear to have been darker beneath than the fore wing, showing large patches of a deeper tint outside the cell on either side, in the basal third of the wing.

In the general proportion of the wings Barbarothea would appear to be more nearly related to Libythea than to any other of the genera of Libytheinæ, living or fossil, but in the possession of a tail or lobe to the lowest median nervule of the hind wings and of a rounded angulation at the lowest inferior subcostal nervule of the fore wing, it approaches more nearly the African Dichora. Possibly it may be found in both these respects, as it certainly is in the former, closer to Prolibythea, since the actual outline of the fore wing in that genus is partly conjectural, the only specimen having a broken tip; but the absence of the falcation so prominent in all recent Libytheinæ will be remarked. In the origin of the outer superior subcostal nervules it also approaches more closely Dichora than any other genera, unless it be again Prolibythea. In the form of the hind wing it is unique; the costal lobe, however, closely resembles that of Prolibythea, but the extreme breadth of the wing as related to its length separates it widely from that and from all other genera of Libytheinæ. In the structure of the antennæ it seems to stand midway between Libythea and Prolibythea, having the slender form and brief club of Prolibythea, but the abrupter tip and slighter distinction between club and stalk, which belongs to Libythea. In the brevity of the apical joint of the palpus, however, we find a marked departure from the ordinary condition of things in Libytheinæ, since here only, in this subfamily, is the apical joint, though relatively longer than in most butterflies, shorter than the middle joint.

Digitized by Google

BARBAROTHEA FLORISSANTI.

Pl. 3, Figs. 1–5.

The single specimen which has been found shows the side view of a butterfly remarkably well preserved, better preserved, indeed, than any known, with the sole exception of Prodryas, from the same beds. But, unfortunately, it is somewhat confused by the mixture of veins and markings of the underlying wings, the margins of which do not altogether coincide. Moreover, the stone upon which it chances to be preserved is of much more irregular surface than was the case with Prodryas, rendering many points obscure which one would wish to see. Thus, though the form of the scales, at least upon the fringe, can be determined, no striation is visible, and where the wings have slipped past each other to a slight extent, the relation of the nervures to the margin can not always be determined with perfect accuracy. Both of the antennæ are preserved, one perfectly, as also are the palpi, the drooping tongue and part of the legs. The length of the body is only faintly and probably indicated by the discoloration of the surface. The fore wings, the outline of which where overlapped by the hind wing is not everywhere altogether clear, have the costal margin very regularly and gently convex, falling, however, with greater rapidity ust before the apex. The outer margin is slightly produced in the subcostal region in a broad swelling between the tip of the subcostal nervule and of the uppermost median nervule; below this the outer margin is not clear. In the hind wing the costal margin is altogether as in *Prolibythea vagabunda*, except that the apical lobe is less pronounced; there is no such emargination of the outer border at the extremity of the costo-subcostal interspace, the outline between the tips of the costal nervure and the lowest median nervule being almost the segment of a circle, apart from the slight and regular crenulation of the wing; this crenulation is most marked in the lobe next the anal angle, and is everywhere produced by the slight projection of the tips of all the nervules; but the tip of the lowest submedian nervule appears to terminate in an emargination and not a projection of the border. The sketch of the neuration (Fig. 1) represents the wing precisely as it appears upon the stone, but as a vein is plainly seen running to the tip of the prominent lobe below this, it is perfectly plain that here the nervure of one wing and the border of another underlying it are delineated. It seems, however, nearly impossible to distribute the two quite properly from the specimen, and it has accordingly been drawn in this way to call attention to this point in future specimens that may be obtained. The markings of the wing, as stated above, under the generic description, are altogether obscure, with very slight exceptions, but it is impossible to mark definitely the limits of the various darker clouds; they are best shown by reference to the plate. The antennæ are composed of about forty-four joints, of which eleven or twelve form

Digitized by Google

a very slightly enlarged club, which is only a little more than half as broad again as the stalk. The whole club shows the separation of the naked surface from that covered by the scales in a very remarkable manner, as is shown best in Fig. 3, where it is most enlarged; and this drawing also shows equally well the three slender carinæ, extending not only upon the club, but upon the stalk as well, certainly throughout its whole apical half, and probably throughout the whole; the joints of the club are nearly half as broad again as long, while the proportions of those of the stalk are reversed to almost exactly the same degree. The basal and middle joints of the palpi are furnished abundantly with moderately long, stiff, projecting hairs, which are directed forward, while on the apical joint these are entirely absent, excepting at the extreme base, or better may be described as entirely recumbent. It would appear to be somewhat doubtful which of the legs are represented upon the stone. One pair is shown, one of them imperfectly, the other almost complete, which would be regarded as the front pair but for their excessive length. They are simple and normal in structure throughout and abundantly and almost equally clothed with fine and crowded spines upon the under surface throughout the tibia and tarsi. The dark portion seen between the base of these legs and the tip of the slender, rather brief tongue can not be regarded as a pair of legs, but only as the clothing of the chest.

Length of body (doubtful), including the palpi, 26 millimeters; last joint of palpi, 2·5 millimeters; middle joint, 3·25 millimeters; antennæ, 12 millimeters; club of same, 3·5 millimeters; width of stalk, 0·25 millimeters; of club, 0·4 millimeter; length of tongue, 5 millimeters; length of fore wing, 28·5 millimeters; breadth of fore wing, 16·5 millimeters; expanse (estimated), 61 millimeters; length of hind wing, 22 millimeters; breadth, 21·5 millimeters; length of (middle?) tibiæ and tarsi, 6·5 millimeters.

Florissant. One specimen; S. H. Long.

HYMENOPTERA--TENTHREDINIDÆ.

ATOCUS (*ἄτοκος*) gen. nov.

In its slender parallel-sided form this genus has all the aspect of a Sirex, but not only is there no extension of the prothorax, but the large head is closely appressed to the thorax. The head is large, rounded subtriangular, broadest posteriorly. The ocelli are apparently only two in number, rather large, situated just at the inner base of the antennæ; these are fourteen-jointed, the first joint very large, twice as stout as, and very much longer than the succeeding, which are simple, longer than broad, and continually diminish in size. Wings with two marginal cells, separated almost beneath the middle of the stigma; four submarginal cells, the first small and nearly circular, the remainder widening and enlarging outwardly, and excepting the apical

Digitized by Google

much longer than broad; first discoidal cell hexagonal, about as long as broad, and but little larger than the first submarginal cell; second discoidal cell of exceptional shape, being oblique and much higher than long, its inner margin beneath the middle of the first discoidal cell, while the third brachial cellule thus made of unusual length is partially or completely divided into two nearly equal parts by a spurious veinlet from the vein above, somewhat as in Cephaleia.

Except for the simple antennæ this curious genus seems to have some relationship to the oriental Tarpa, and I can not find anything nearer to it unless it be Cephaleia. It is a striking form.

A single species occurs at Florissant.

ATOCUS DEFESSUS.

Pl. 1, Fig. 5.

The whole body is uniformly dark, the wings without markings except the fusco-fuliginous stigma; the antennæ are about half as long again as the width of the head, and beyond the first joint taper so as to be about half as broad at apex as at second joint; the outer is about twice as long as the inner marginal cell which lies wholly beneath the stigma, and is about as broad at base as at apex; the first submarginal cell on the other hand lies almost wholly before the stigma, and has as much an appearance of belonging to the marginal as to the submarginal series; the cross veins at the outer sides of the first submarginal and first and second discoidal cells form a pretty regular zigzag across the middle of the wing.

Length of body, 10·5 millimeters; antennæ, 3·25 millimeters; fore wings, 7·5 millimeters.

Florissant, Colorado. One specimen, No. 11983.

Digitized by Google

Digitized by Google

PLATES.

Digitized by Google

Digitized by Google

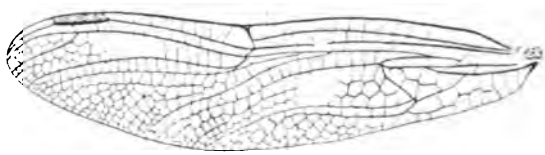
PLATE I.

Digitized by Google

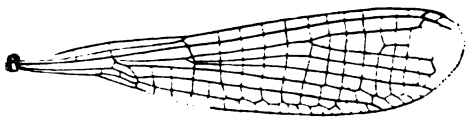
EXPLANATION OF PLATE I.

Fig. 1. Stenogomphus carletoni; ¾.
2. Trichocnemis aliena; ¾.
3. Cicada grandiosa; ¾.
4. Carabites exanimus; ¾
5. Atocus defessus; antenna, much enlarged.
6. Atocus defessus, complete; ¾.

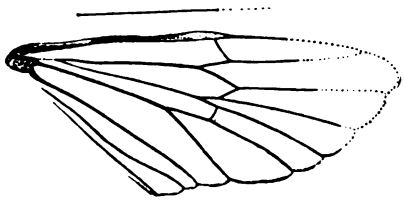
Digitized by Google



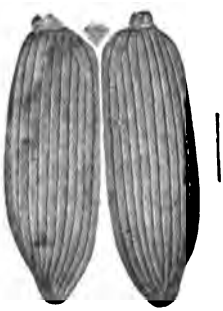
1



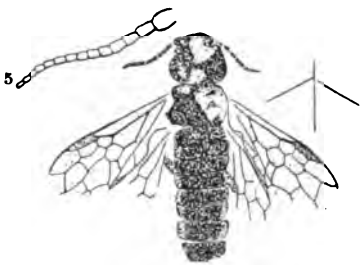
2



3



4



5 6

Digitized by Google

Digitized by Google

PLATE II.

Digitized by Google

EXPLANATION OF PLATE II.

Fig. 1. Palœstrus oligocenus, body and wings; ⅞.
2. Nosotetocus marcovi; ⅞.
3. The same, the antennæ further enlarged; 1½.
4. Palœstrus oligocenus, basal joint of abdomen and leg; ⅞.
5. Mycetophætus intermedius; ⅞.

Digitized by Google

1

2

3

4

5

Digitized by Google

Digitized by Google

PLATE III.

Digitized by Google

EXPLANATION OF PLATE III.

Fig. 1. Barbarothea florissanti, outline and neuration in the position in which it is preserved; ⅔.

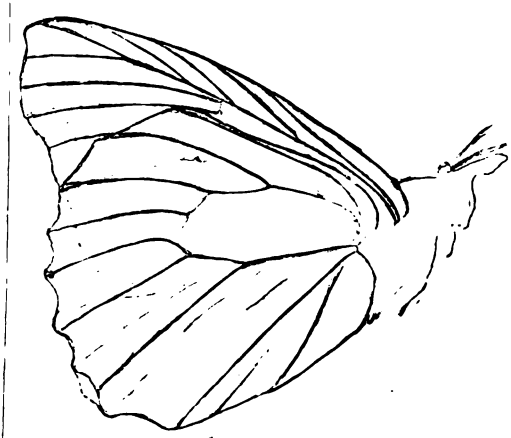
2. The same, its general appearance on the stone; ½.

3. The same, right antenna, much enlarged; ⅘.

4. The same, sketch of head and appendages except wings, enlarged; ⅔.

5. The same, the neuration, as far as preserved, that of each wing separated; ⅔.

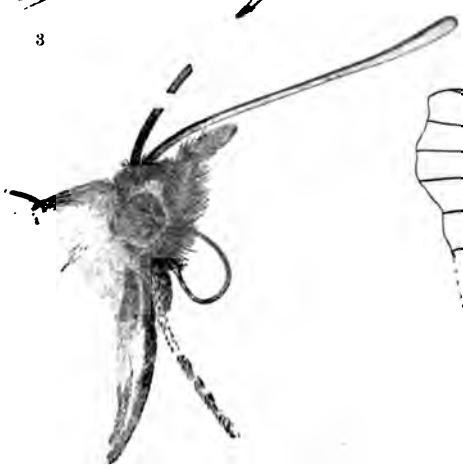
Digitized by Google



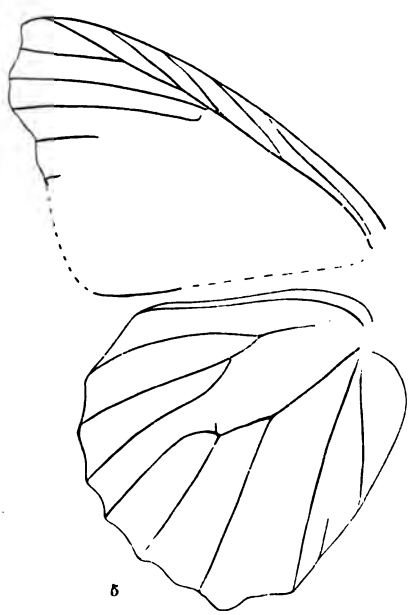
1

2

3



4



5

Digitized by Google

Digitized by Google

INDEX.

	Page.
Acræinæ	21
aliena, Trichocnemis	12
Atocus	24
Atocus defessus	25
Barbarothea	21
Barbarothea florrissanti	23
Byrrhidæ	16
Byrrhus exanimatus	16
Cacus	13
Carabidæ	17
Carabites	17
Carabites exanimus	17
carletoni, Stenogomphus	14
Cephaleia	25
Cicada	15
Cicada grandiosa	15
Cicadidæ	15
Coleoptera	16
defessus, Atocus	25
Dichora	21, 22
Diptera	18
exanimus, Carabites	17
Fidicina	15
florissanti, Barbarothea	23
Gomphina	13
Gomphoides	13
Gomphoides bifasciata	14
brevipes	14
stigmata	14
grandiosa, Cicada	15
Hemicnemis cyanops	12
Hemiptera	15
Hymenoptera	24
Hypoderma	19
Lepidoptera	20
Libythea	21, 22
Libytheinæ	20
Lindenia	13
marcovi, Nosotetocus	17
Muscaria	18
Mycetobinæ	20
Mycetophætinæ	19
Mycetophætus	20
Mycetophætus intermedius	20
Mycetophilidæ	19
Neuroptera	12
Nosodendron	16
Nosotetocus	16
Nosotetocus marcovi	17
Nymphalidæ	20
Odonata	12
Œstridæ	18
oligocenus, Palcestrus	19
Palcestrus	18
Palcestrus oligocenus	19
Platycnemis	12
Platycnemis icarus	12
Prodryas	23
Progomphus	13
Prolibythea	20, 22
Prolibythea vagabunda	21, 23
Pterostichini	17
Sciophila	20
Sciophilinæ	20
Sirex	24
Stenogomphus	13
Stenogomphus carletoni	14
Tarpa	25
Tenthredinidæ	24
Trichocnemis	12
Trichocnemis aliena	12
icarus	13

Digitized by Google

Digitized by Google

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 94

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

THE MECHANISM OF SOLID VISCOSITY

BY

CARL BARUS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Letter of transmittal	13
Preface	15
CHAPTER I. Tensile, drawn, and other strains in their bearing on Maxwell's theory of viscosity	17
Introductory	17
Apparatus	18
Data for drawn wires	18
Data for stretched wires	24
Inferences	26
CHAPTER II. The two species of molecular break-up which promote viscous deformation	30
Introductory	30
Motional annealing defined	30
Strain, electric resistance, and viscosity	31
Temper, electric resistance, and viscosity	31
Data relative to temper, electric resistance, and viscosity	31
Discussion of results	33
Data for cyclic twisting	33
Discussion of results of cyclic twisting	37
The marked feature	37
Analogy with thermal annealing	38
CHAPTER III. The effect of mechanical strain on the carburation of steel	40
Introductory	40
Drowne's experiments	40
The present method	40
Method of experiment	41
Results obtained	41
Tables	42
Discussion	44
Inconsistency of the results	44
Errors of the method	45
Temperature	45
Concentration of acid	45
Solution in air and in hydrogen	45
Rate of solution	46
Structural density	46
Summary	46
Osmond's α and β iron	47
CHAPTER IV. The effect of strain on the rate of solution of steel	48
Introductory	48
Method	48
Tables	49

Digitized by Google

Page.

CHAPTER IV. The effect of strain on the rate of solution of steel—Continued.
Discussion 57
Incidental errors 57
Effect of surface 58
Effect of diffusion 58
Wires originally soft 59
Wires annealed 60
Relation to Browne's inferences 61
Summary 61
CHAPTER V. The hydroelectric effect of changes of molecular configuration. 63
Introductory 63
Apparatus 63
Experiments 64
Zero method 64
Results for iron 64
Discussion of results 66
Data for divers metals 66
Effects classified 69
Discussion of errors 70
Variable capacity 70
Single wires 72
Summary 72
CHAPTER VI. Secular annealing of cold hard steel 74
Introductory 74
Results for homogeneity of rods 75
Mass constants of rods 76
Electrical constants of rods 77
Summary 79
CHAPTER VII. The viscosity of electrolyzing glass 80
Apparatus 80
Results 81
Inferences 82
CHAPTER VIII. The electrical resistance of stressed glass 85
Introductory 85
Apparatus 86
Experiments 86
Data for 350° 86
Data for 100° 88
Data for 185° 89
Results of twisting 90
Differential apparatus 91
Results for torsion 91
Character of traction effects 91
Results for traction at 190° 92
Discussion of these results 94
Traction at 100° 94
Further results at 100° 95
Dimensional change due to torsion 96
Effect of temperature 96
Traction at 360° 97
Summary 98
Degree of molecular instability of glass 98
CHAPTER IX. The energy potentialized in permanent changes of molecular configuration 101
Introductory 101

Digitized by Google

Page.

CHAPTER IX. The energy potentialized in permanent changes of molecular configuration—Continued.
Apparatus 101
Results 103
Discussion of errors 104
Successive stretching 105
Results of improved methods 106
Summary 107
CHAPTER X. The chemical equilibrium of solids in its relation to pressure and to temperature 109
Earlier researches 109
Apparatus 110
Compressor 110
Vapor baths 110
Insulation 110
The resistance tube 111
Arrangement for testing insulation 113
Digression 113
Resistance measurement 114
Galvanometer 114
Other adjustments 114
Observations 114
Tables explained 114
Remarks on the table 115
Electromotive force 116
Remarks on the table 116
Pressure coefficient of sperm oil 117
Pressure coefficient of gasoline 117
Pressure coefficient of petroleum 118
Pressure coefficient of thin machine oil 120
Pressure coefficient of thick machine oil 122
Digest 123
Deductions 124
Effect of pressure 124
Temporary and permanent effects 124
Chart 125
Pressure and chemical equilibrium 125
Effect of temperature 125
Molecular effects of stress 125
Hysteresis 126
Magnetic hysteresis 127
Mechanism of viscosity 128
Electrical effects of œolotropic stress 130
Unavoidable errors 130
Polarization 130
Insulators 130
Shifting isothermal planes 130
Electromotive force 131
Short-circuiting 132
Electromotive force and pressure 132
Graphic representation 133
Electric instability of hydrocarbon oils 134
Conclusion 135
Index 137

Digitized by Google

Digitized by Google

ILLUSTRATIONS.

		Page.
FIG. 1.	Apparatus for comparing viscous deformations	19
2.	Time variation of viscous deformation in case of soft steel transformed by temper, drawn strain, traction, and torsion, respectively	28
3.	Withdrawn.	
4.	Apparatus for measuring the hydroelectric effect of stretching	64
5.	Apparatus for testing the viscosity of electrolyzing glass	81
6.	Apparatus for testing the viscosity of electrolyzing glass	82
7.	Apparatus for testing the viscosity of stressed glass	86
8.	Apparatus for testing the viscosity of stressed glass	88
9.	Apparatus for testing the viscosity of stressed glass	88
10.	Apparatus for testing the viscosity of stressed glass 200°	90
11.	Apparatus for testing the viscosity of stressed glass 100°	90
12.	Apparatus available at 360°	97
13.	Apparatus for measuring the thermal effect of stretching	102
14.	Tube for measuring the pressure increments of the electric resistance of glass	110
15.	Diagram of resistance tube in place	111
16.	Improved form of resistance tube.	112
17.	Arrangement for measuring the pressure increments of the electric resistance of liquid insulators	113
18.	Pressure coefficient and temperature for sperm oil and for glass	117
19.	Pressure coefficient and temperature for gasoline	118
20.	Pressure coefficient and temperature for petroleum and for glass	120
21.	Pressure coefficient and temperature for thin mineral machine oil and for glass	122
22.	Pressure coefficient and temperature for thick mineral machine oil and for glass	124
23.	Diagram	131
24.	Charts showing the oscillation of the electric conductivity of glass and of viscous hydrocarbon oil	133

Digitized by Google

Digitized by Google

TABLES.

		Page.
TABLE 1.	Viscosity of hard-drawn steel wire compared with soft.	20
2.	Viscosity of hard-drawn steel wire compared with soft	21
3.	Viscosity of hard-drawn steel wire compared with soft	22
4.	Viscous effect of moderate traction	23
5.	Digest for hard and soft wires	23
6.	Viscous effect of cyclic traction	25
7.	Viscous effect of motional annealing	32
8.	Electrical effect of motional annealing	33
9.	Viscous deformation in case of cyclic twisting	34
10.	Graphitic carbon in soft and in drawn steel	42
11.	Solution of soft steel	49
12.	Solution of drawn steel	50
13.	Solution of soft steel	51
14.	Solution of drawn steel	53
15.	Solution of drawn steel	55
16.	Solution of tempered and soft steels	57
17.	Digest for originally soft wires	59
18.	Digest for wires annealed in air	60
19.	Digest for hard wires	60
20.	Hydroelectric effect of tensile strain, iron	65
21.	Hydroelectric effect of tensile strain, German silver	66
22.	Hydroelectric effect of tensile strain, brass	67
23.	Hydroelectric effect of tensile strain, copper	67
24.	Hydroelectric effect of tensile strain, iron	67
25.	Hydroelectric effect of stretching, brass	68
26.	Hydroelectric effect of stretching, iron	68
27.	Hydroelectric effect of stretching, miscellaneous	68
28.	Digest	71
29.	Digest	71
30.	Longitudinal uniformity of temper	76
31.	Mass constants of glass-hard steel rods	77
32.	Specific resistance of glass-hard steel rods	77
33.	Specific resistance of glass-hard steel rods	78
34.	Viscosity of electrolyzing glass	83
35.	Viscosity of electrolyzing glass	83
36.	Viscosity of electrolyzing glass	84
37.	Resistance of glass across the lines of stress	87
38.	Resistance of stressed glass at 100°	87
39.	Resistance of stressed glass at 180°	89
40.	Resistance of stretched glass at 100°	94
41.	Resistance of stressed glass at 100°	95
42.	Longitudinal extension of the tubes	96
43.	Resistance of stretched glass at 360°	98

Digitized by Google

		Page.
TABLE 44.	Energy potentialized in tensile strains	103
45.	Variation of density of stretched wire	104
46.	Successive stretching	106
47.	Energy potentialized in tensile strains	107
48.	Apparent effect of pressure on resistance of glass	115
49.	Apparent effect of pressure on electromotive force	116
50.	The insulation and pressure coefficient of sperm oil	118
51.	Behavior of gasoline under pressure	119
52.	Insulation and pressure coefficient of petroleum	119
53.	Insulation of pressure coefficient of thin mineral machine oil	121
54.	Pressure coefficient of glass surrounded by mineral machine oil	121
55.	Insulation of pressure coefficient of sticky mineral machine oil	123
56.	Breakdown of resistance in case of oils examined	123
57.	Breakdown of resistance in case of glass	123
58.	Allowance for increments of electromotive force	132
59.	Rate of thermal variation of pressure coefficient	134

Digitized by Google

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF CHEMISTRY,
Washington, D. C., August 31, 1891.

SIR: I transmit herewith a manuscript by Dr. Carl Barus entitled "The Mechanism of Solid Viscosity," with the request that it be published as a bulletin of the Survey. It represents work done in the physical laboratory.

Very respectfully,

F. W. CLARKE,
Chief Chemist.

Hon. J. W. POWELL,
Director.

Digitized by Google

Digitized by Google

PREFACE.

In the following pages I have brought together such of my experiments on the viscosity of solids as have an immediate bearing on the molecular mechanism by which viscous motion in solids is promoted. The bulletin is therefore a continuation of the previous publication (Bulletin 73), in which the phenomenon of viscosity was considered more particularly with reference to its physical manifestations. Most of the chapters of the present work are short, and a preliminary survey of the work done can be expeditiously made by consulting the table of contents.

C. B.

15

Digitized by Google

Digitized by Google

THE MECHANISM OF SOLID VISCOSITY.

BY CARL BARUS.

CHAPTER I.

TENSILE, DRAWN, AND OTHER STRAINS IN THEIR BEARING ON MAXWELL'S THEORY OF VISCOSITY.

INTRODUCTORY.

1. It is known that the effect of drawing metallic wires through a draw-plate is a marked decrease of the viscosity of the originally soft metal. The diminution increases with the intensity of strain imparted. It is not so well known that the viscous effect of a tensile strain applied in any degree to the same originally soft metal is after straining almost *nil* in comparison. Kohlrausch[1] and his pupils, Streintz[2] and others, more recently and in extensive researches Mr. Herbert Tomlinson,[3] have occupied themselves with these phenomena. The results of these observers are in general accord, and agree well enough with my work that special publication of new data might appear superfluous. Nevertheless, as steel has been but sparingly dealt with, and as results fitting at once into my diagrams are essential to my purpose, I have found it desirable to communicate them. Apart from these considerations the observations which I need must be made with minute reference to Maxwell's theory. In this respect the earlier work is seriously lacking.

The striking difference in the permanent viscous effect produced by the action of the two strains is particularly surprising, because the strains are imparted by mechanical processes not altogether dissimilar. The action of wire-pulling, however, accompanied as it is by surface compression as well as longitudinal extension, is conducive to the permanent retention of high-strain intensities, because it imparts to the wire an arched structure. In steel, at least, there is a dense shell surrounding an unusually rare core in such a way that the density of the

[1] Kohlrausch's original and fundamental researches are given in my earlier papers. Here I need refer only to Schroeder, Wied. Ann., vol. 28, 1886, p. 354.

[2] Streintz, Pogg. Ann., vol. 153, 1874, pp. 395, 396, 411.

[3] H. Tomlinson, Phil. Trans., 1886, vol. 2, pp. 801 to 837. The variety of strains and metals examined in this paper give it unique value as regards the subject of the present section.

Digitized by Google

whole mass is materially lessened.[1] Conditions favorable to the retention of high-strain intensities are also conditions favorable to the occurrence of molecular instability. Hence the marked loss of viscosity of a drawn wire, as compared, cæt. par., with a soft wire. This premised, it appears that in the case of a wire hardened by simple traction the strain retained after traction is of insufficient intensity to be accompanied by marked molecular instability. More rigorously: if the wire during traction has experienced a strain S, which strain after the tensile stress is withdrawn diminishes to S′ ($S > S'$), then the wire need exhibit no change of viscous quality. For in the above cases of thermal annealing and torsional motional annealing (§§ 2, 9), the greater tensile strain S, supposing its action sufficiently prolonged, has wiped out all motional instability for strains $S' < S$; so it follows here that to evoke viscous deformation by aid of tensile strains, the wire must be examined *during traction*, and preferably under conditions of strain near the limit of rupture.

APPARATUS.

2. The apparatus used in these experiments is shown in Fig. 1, in which *ab* and *cd* are the two steel wires to be counter-twisted. The system is fastened above and below to two massive torsion-circles, A and B, respectively. The inner ends of the wires are joined by a strong brass rod *bc*, carrying a symmetrical circular platform near the lower end, on which the lead scale-weights C C′ C″, etc. (4 kilos. to 5 kilos. each) may be supported. In order to facilitate quick work, the connecting rod *bc* is provided with a pair of cross-vanes, D, D′, submerged in the water contained in an annular trough, *fgih f′g′i′h′*. Finally, the mirror *m* adjustably attached to the rod *bc* (readings by telescope and scale) indicates the difference of viscous motion of the two wires in consequence of a fixed rate of twist stored between A and B. I may add that the rod *bc* can easily be chosen light enough, compatibly with strength, to introduce no viscous effect of its own.

DATA FOR DRAWN WIRES.

3. The data to test the above are given in the following tables, of which Nos. 1, 2, 3 exhibit the behavior of some drawn steel wires. In each case the comparison is made with my steel normal No. 15 (the lower wire in Fig. 1, An. 450° and twisted to permanent viscous qualities). The drawn wire in Table 1 is in the moderately resilient bright commercial state, very soft to the file. The wire in Table 2 has been drawn down from a larger diameter and the same state of hardness to an extreme of brittle resilience. The wire of Table 3 finally was first softened by heating to redness in air and then drawn down to brittle resilience. Dimensions are given in the tables, ρ being the radius and l

[1] Cf. Baumeister: Dissert., Würzburg, 1888.

Digitized by Google

and l' the lengths of the wires. $L = l + l'$. The impressed rate of twist in radians is given under τ. The observed permanent torsion is $2(\varphi + \varphi')$. θ and θ' are the temperatures of the drawn and normal wires respec-

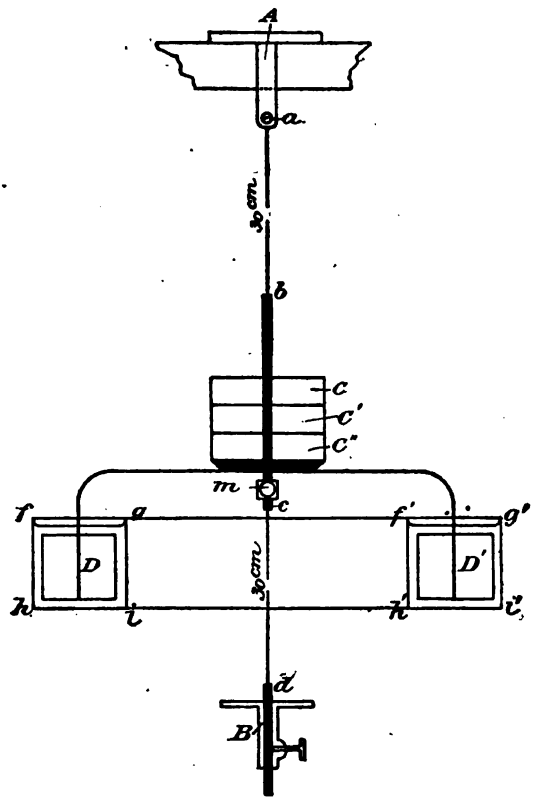


Fig. 1.—Apparatus for comparing viscous deformations.

tively. The former is constant, the latter (θ') at first 30°, and then 100°; so that the examination is made at two temperatures, in order to compare corresponding viscous effects of the drawn strain and of temper. As will be more fully shown below, § 5, $\tau + 2(\varphi + \varphi' (= 2\pi/L$, and $(\varphi - \varphi')/\tau$ is the viscous deformation indicated by the mirror, per unit of length of system, per unit of τ. It must be borne in mind (cf. § 13) that $(\varphi - \varphi')/\tau$ is a function of τ, for which reason the same rate of twist is applied to the wires throughout; applied, moreover, positively and negatively for each value of θ'. Finally, after testing the wire in the drawn state, it was softened by heating to redness in air and again tested. In this case viscous motion at the mirror nearly ceases, thus affording an excellent check on the validity of the experiments.

Digitized by Google

TABLE 1.—*Viscosity of hard-drawn steel wire compared with soft.*

$2\rho = \cdot 082$ cm.; $L = l + l' = 30$ cm. $+ 30$ cm.

Wire drawn moderately resilient.				Same wire annealed at red heat in air.			
θ / θ'	$\frac{\tau}{2(\phi+\phi')}$	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$	θ / θ'	$\frac{\tau}{2(\phi+\phi')}$	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$
		h. m.				h. m.	
30	+ ·1041	1 36		30	+ ·1034	3 08	
30		38	·00	30		10	+ ·00
		39	1·08			11	·10
		44	3·33			13	·07
	+ ·0037	48	4·43			16	·10
					+ ·0014	20	·14
30	— ·0989	1 51		30	— ·1019	3 22	
30		53	— ·00	30		24	+ ·00
		54	—1·01			25	·00
		56	—2·35			27	·03
		59	—3·58			30	·07
	— ·0058	63	—4·61		— ·0028	34	·07
100	+ ·0989	2 24		100	+ ·1047	4 00	
30		26	·00	30		02	·00
		27	2·83			03	·33
		29	6·53			05	·78
		32	10·23			08	1·31
	+ ·0058	36	13·60		+ ·0000	12	1·44
100	— ·0931	2 39		100	— ·1004	4 13	
30		41	·00	30		15	— ·00
		42	3·03			16	— ·33
		44	7·07			18	— ·88
	— ·0116	47	10·77		— ·0043	21	1·65

Digitized by Google

TABLE 2.—*Viscosity of hard-drawn steel wire compared with soft.*

$2\rho = \cdot 082$ cm.; $L = l + l' = 30$ cm. $+ 30$ cm.

Wire drawn ($2\rho = \cdot 13$ cm. to $\cdot 08$ cm.) very resilient.				Same wire annealed at red heat in air.			
θ θ'	τ $2(\phi+\phi')$	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$	θ θ'	τ $2(\phi+\phi')$	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$
		h. m.				h. m.	
30	+ ·0959	5 52		30	— ·1019	1 32	
30		54	·00	30		34	
		55	4·37			35	— ·00
		57	10·10			37	— ·13
		60	15·68			40	— ·17
		63	19·46		— ·0028	44	— ·20
	+ ·0087	6 30	34·47				
30	— ·0916	6 32		30	+ ·1034	1 45	
30		34	— ·00	30		47	+ ·00
		35	— 4·72			48	·10
		37	—10·50			50	·10
		40	—16·16			53	·15
	— ·0131	44	—20·88		+ ·0014	57	·21
100	+ ·0916	6 52		100	— ·1019	2 00	
30		53	·00	30		02	— ·00
		54	16·80			03	— ·47
		55	27·30			05	— ·91
		56	34·50			08	—1·28
	+ ·0131	56·7	39·05		— ·0028	12	
100	— ·0873	6 58			Accident.		
30		59	— ·00				
		60	—16·80				
		61	—26·30				
		62	—33·70				
	— ·0175	63	—39·40				

Digitized by Google

TABLE 3.—*Viscosity of hard-drawn steel wire compared with soft.*

$2\rho = \cdot 082$; $l = l' =$ cm.; $\theta = \theta' = 30°$. Wire drawn ($2\rho = \cdot 13$ to $\cdot 08$ cm.) very resilient.

$\frac{\tau}{(2\phi+\phi')}$	Time.	$10^3 \times (\phi - \phi')/\tau$	$\frac{\tau}{2(\phi+\phi')}$	Time.	$10^3 \times (\phi - \phi)/\tau$
	h. m.			*h. m.*	
+ ·099	3 40		+ ·099	5 17	
	41	·00		18	·00
	42	3·77		19	2·83
	43	6·39		20	4·44
	44	8·30		21	5·80
	45	9·80		22	6·80
	46	11·10		23	7·70
+ ·006	47	12·20		24	8·40
			+ ·006	25	9·10
— ·099	5 02		— ·099	5 35	
	04	— ·00		36	— ·00
	05	— 2·70		37	—2·35
	06	— 4·65		38	—3·77
	07	— 6·06		40	—5·80
	08	— 7·35	— ·006	45	—8·90
	09	— 8·40	+ ·099	5 46	
	10	— 9·30		47	·00
— ·096	12	—10·90		48	2·10
				49	3·36
				50	4·30
				52	5·73
			+ ·006	56	7·70

In Table 4 I give results for the viscous effect of moderate values of tensile strain on a plan identical with the above. The pull on the strained wire (the normal being No. 15) is indicated in the first column in kilogrames. The maximum pull which these wires will bear was computed to be between 30 kilos. and 50 kilos. It was found to be 45 kilos. in some cases experimentally. Inasmuch as I here apply 8·4 kilos., the pull applied is 17 per cent to 25 per cent of the load producing rupture.

Digitized by Google

TABLE 4.—*Viscous effect of moderate traction.*

Soft steel wire. $2\rho = \cdot 082$ cm.; $l = l' = 30$ cm.; $\theta = \theta' = 30°$; $\tau = \cdot 100$.

Pull.	Time.	$10^3 \times (\phi - \phi')/\tau$	Pull.	Time.	$10^3 \times (\phi - \phi')/\tau$
Kilos.	*h. m.*		*Kilos.*	*h. m.*	
0	5 13		4·8	5 59	
	15	·00		6 01	·00
	17	·03		03	·07
	20	·10		06	—·07
	24	·13		10	—·13
	29	·17		23	—·27
	35	·18		31	—·40
2·4	5 36	·00	8·4	6 32	
	37	·07		47	·00
	38	·13		7 09	—·27
	40	·23		23	—·27
	43	·23		21 00	—·07
	48	·27			
	52	·40			
	58				

The results of Tables 1, 2, and 3 clearly show the marked influence of the drawn strain in effecting diminution of viscosity. Wires drawn only moderately resilient are of the same low order of viscosity as glass-hard wires. Again, if the wires are drawn very resilient the reduction of the viscosity of the originally soft wire is enormous. To eliminate the effect of different degrees of softness, I also drew down a wire after heating in air (Table 3). The results are in accord with Tables 1 and 2.

Some insight into these results is expeditiously obtained by constructing tangents at like time-points of the curves. This is approximately done in the small summary following (Table 5), by subtracting the values of $(\varphi - \varphi')/\tau$ for the beginning and end of the second minute after twisting. Similar values for stretched wire are given in the last two columns, kg. denoting the load.

TABLE 5.—*Digest for the hard and soft wires in Tables 1, 2, 3, and 4.*

θ	τ	Drawn. $\Delta\frac{\phi-\phi'}{\tau} \times 10^3$	Soft. $\Delta\frac{\phi-\phi'}{\tau} \times 10^1$	θ	τ	Drawn. $\Delta\frac{\phi-\phi'}{\tau} \times 10^3$	Soft. $\Delta\frac{\phi-\phi'}{\tau} \times 10^3$
30	+·10	1·08	·10	30	+·10	4·37	·00
80	—·10	—1·01	—·00	30	—·09	—4·72	—·10
100	+·10	2·83	·33	100	+·09	10·50	·47
100	—·09	—3·03	—·33	100	—·09	— 9·50	

Digitized by Google

TABLE 5.—*Digest for the hard and soft wires in Tables 1, 2, 3, and 4*—Continued.

θ	τ	Drawn. $\Delta\frac{\phi-\phi'}{\tau}\times 10^3$	kg.	τ	Stretched. $\Delta\frac{\phi-\phi'}{\tau}\times 10^3$
30	+·10	+2·62	0	·10	+·03
30	−·10	−2·70	2·4	·10	+·06
30	+·10	+1·61	4·8	·10	+·07
30	−·10	−1·42	8·4	·10	
30	+·10	+1·26			

From this table the small effect of traction in case of loads below 25 per cent of the breaking stress is specially manifest; an effect negligible in comparison with the diminution of viscosity due to the drawn strain. For the sake of orientation I may assume that corresponding values of $\Delta(\varphi-\varphi')/\tau$ for glass-hardness would at 30° be about $1/10^3$ to $2/10^3$—that is, about equal to this quantity in the case of a moderately resilient wire. In general, the results for the drawn strain both at 30° and at 100° corroborate and accentuate the results already obtained for temper[1], so that the further discussion can be made as in my earlier papers, and may be waived here. I add only that the effect of drawing in case of steel is a decrease of the density of the soft metal; for instance,

Rods.	A.	B.	C.
Originally soft	7·76	7·72	7·68
Drawn very resilient . .	7·72	7·64	7·64
Softened after drawing .	7·80	7·73	

It appears that in this respect also the drawn strain and temper are similar.

DATA FOR STRETCHED WIRES.

4. Returning to the case of simple traction, the changes of sign of $(\varphi-\varphi')/\tau$ suggesting increase of viscosity for loads slightly greater than 5 kilos., indicate that here, as in the case of motional annealing due to torsion, the initial effects are an increase of viscosity. Nevertheless, the obscurely small viscous variations due to traction do not admit of interpretation, unless supplemented by data for very much larger loads. Again, it is desirable and quite feasible, by aid of the apparatus discussed above, to operate cyclically; in which case the results must be such as to bear on the lag-quality of solids under stress.

In the following table (6) I have therefore inserted some data for larger pulls. Traction increases successively as far as 90 per cent of the breaking stress. It will be superfluous to give more than a few typical examples; and the tables can be further abbreviated, because in the stress-decreasing phase of the cycles the viscous effect of loads P

[1] Phil. Mag., 5th. ser., vol. 26, 1888, p. 205 et seq., cf. Bull. U. S. Geol. Surv. No. 78, Chap. III, 1891.

Digitized by Google

below the maximum employed is nil, § 1, and therefore sufficiently given by the final load zero. To retain a fixed rate of torsion, τ, it is necessary to twist the wires anew after each of the larger loads; in other words, to bring back the same scale-division into the telescope at the outset of each experiment. Otherwise the torsion seriously decreases in consequence of the rapid viscous deformation of the loaded wire.

TABLE 6.—*Viscous effect of cyclic traction.*

Soft steel. $2\rho = \cdot 081$ centimeters; $l = l' = \cdot 30$ centimeters.

P	τ	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$	P	τ	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$
Kg.	*Rad.*	*h. m.*	*Rad.*	*Kg.*	*Rad.*	*h. m.*	*Rad.*
0	—·10	11 31		0	+·13	10 22	
		33	+ ·00			28	·00
		40	+2·16			31	·00
		51	+3·35			36	·00
						44	·19
9	—·10	11 52					
		53	+ ·00	9	+·13	10 45	
		56	+ ·23			46	·00
		59	+ ·45			49	·38
		64	+ ·52			52	·55
						55	·63
18	—·10	11 64					
		67	·00	18	+·13	10 56	
		71	— ·12			59	·00
		83	— ·37			61	·05
						65	·08
27	—·10	12 24				68	·12
		27	— ·00				
		30	— ·37	27	+·13	11 09	
		37	— ·48			10	·00
						13	·45
36	—·10	12 39				16	·78
		40	— ·00			19	1·04
		46	—1·64				
		53	—2·53	36	+·13	11 20	
						21	·00
40	—·10	12 53				24	1·90
		55	·00			27	3·37
		60	—2·08			30	4·61
		65	—5·07				
		78	—9·62	40	+·13	11 31	
						34	·00
40	(*)	1 22	$(\phi-\phi') \times 16^6$			36	2·71
		23	— 0			38	4·84
		25	—1440			41	7·58
		27	—1750				
		30	—2120	0	+·13	11 42	
						45	·00
40	(*)	1 32				50	·09
		35	— 0			60	·09
		37	— 200				
		39	— 390	0	+·13	12 01	
						04	·00
0	(*)	1 51				09	—·18
		52	·00			13	—·27
		55	+ ·30				
		3 30	+1·10				

* Twisted again.

Digitized by Google

TABLE 6.—*Viscous effect of cyclic traction*—Continued.

Soft steel. $2\rho = .081$ centimeters; $l = l' = .30$ centimeters.

P	τ	Time.	$\frac{\phi - {}'\phi}{\tau} \times 10^3$	P	τ	Time.	$\frac{\phi - \phi'}{\tau} \times 10^3$
Kg.	*Rad.*	*h. m.*	*Rad.*	*Kg.*	*Rad.*	*h. m.*	*Rad.*
20	+·13	12 14		38	+·13	12 45	
		15	·00			47	·00
		18	·00			50	1·53
		22	·05			53	2·67
		24	·07			56	3·79
		28	·09			60	5·21
29	+·13	12 30		42	+·13	1 01	
		31	·00			04	·00
		33	·11			07	9·1
		36	·25			10	14·9
		40	·33			13	19·8
		44	·44			17	25·1
				Wire breaks at P = 46 kg.			

In adding the successive loads care was taken to avoid vibration and jarring; but without special machinery it is impossible to protect the system completely against it. To this cause I attribute certain irregularities of sequence which these and others of my results exhibit. Their general significance is none the less definite. The effect of traction is diminution of viscosity, increasing at an accelerated rate in proportion as stress approaches the limit of rupture. Indeed, by sufficiently increasing stress, viscosity may be diminished in any degree whatever. The singularly curious feature of these experiments is this: that with the removal of load the viscous effect of traction almost entirely vanishes. It is in this respect that the present experiments bear directly on the truth of Maxwell's theory; for it is only during the interval within which conditions favorable to molecular break-up are *forcibly* maintained that the wires exhibit a low order of viscosity of a sufficiently marked degree to compare with the viscous effect of drawn strains and of temper, where instabilities are structurally retained.

It follows, in general, that slight applications of mechanical treatment (twisting, traction, etc.), inasmuch as they decrease in number the motionally unstable configurations of the soft wire, increase viscosity (motional annealing). If this treatment is intensified beyond a critical stage—in other words, if stress is increased sufficiently beyond the limits of resilience and toward the limits of rupture—then viscosity is again seriously decreased. For the action of stress has now become such as to introduce its own specific instability, whereby viscous deformation is again promoted.

INFERENCES.

5. Having thus substantiated the remarks of § 1, and shown that the accordant results of the earlier observers and my own are such as fol-

Digitized by Google

low naturally from Maxwell's theory, it is expedient to give a graphic representation of the more important differential data (i. e., differences between strained and soft metal for each case of stress) in hand. In figure 2 the viscous deformation $(\varphi - \varphi')/\tau$ produced by the action of a fixed rate of twist τ, is represented as ordinate, time as abscissa. The material is steel, the originally soft state of which has been transformed by temper (glass-hardness), drawn strain (wire-plate), tensile strain, and torsion respectively. Curves are given for intense values and for moderate values of stress. The nature of the problem precludes greater definiteness as to stress data. In case of traction infinitesimally below the point of rupture, for instance, viscous deformation would occur with such extreme rapidity that its diagrammatic representation would be a vertical line.

Again, in case of traction of sufficiently small value, the curve would be a horizontal line coinciding with "soft," or even a curve below it (motional annealing). In a measure this is true of the other strains; and I have therefore expediently inserted the values for deformations actually found.

The general outcome of the present paper is this, that the effect of strain of whatever kind, applied in sufficient intensity to homogeneous soft steel, is marked diminution of viscosity. Again, inasmuch as the underlying cause of viscous deformation is the occurrence of unstable configurations the number of which is being reduced in the course of viscous motion, Maxwell's theory naturally suggests the applicability of exponential equations for the description of the time relations of such motion. From another point of view it appears that the loss of viscosity experienced by a given metal, under action of a given kind of strain, may not inappropriately be used as a measure of its intensity. Finally, the curious observation, that in all the cases given loss of viscosity has taken place simultaneously with increase of hardness, is one of the suggestive results of the experiments made.

Quite recently Auerbach,[1] in applying a method for the absolute evaluation of hardness due to Hertz, has shown that hardness and elasticity are associated quantities, i. e., quantities between the corresponding variations of which a close agreement is maintained irrespective of the body operated on. Hence the above results show a fundamental distinction between viscosity and elasticity.

From experiments made on the behavior of iron in passing through the temperature of recalescence Osmond[2] was led to conclude that all the phenomena of hardness are due to a second or β variety of iron. This β iron may be formed from ordinary or α iron, either spontaneously by heating above a certain high temperature, below which, however, it is unstable and passes back to α iron on cooling

[1] Auerbach: Wied. Ann., vol. 43, 1891, p. 61. Other references are there given.

[2] Osmond: Annales des Mines, July-August, 1888, "Introduction," and elsewhere. Cf. Bull. U. S. Geol. Surv. No. 73, p. 51, 1891.

Digitized by Google

except under certain conditions, or β iron may be formed artificially by the action of pressure of any kind applied below the critical tem-

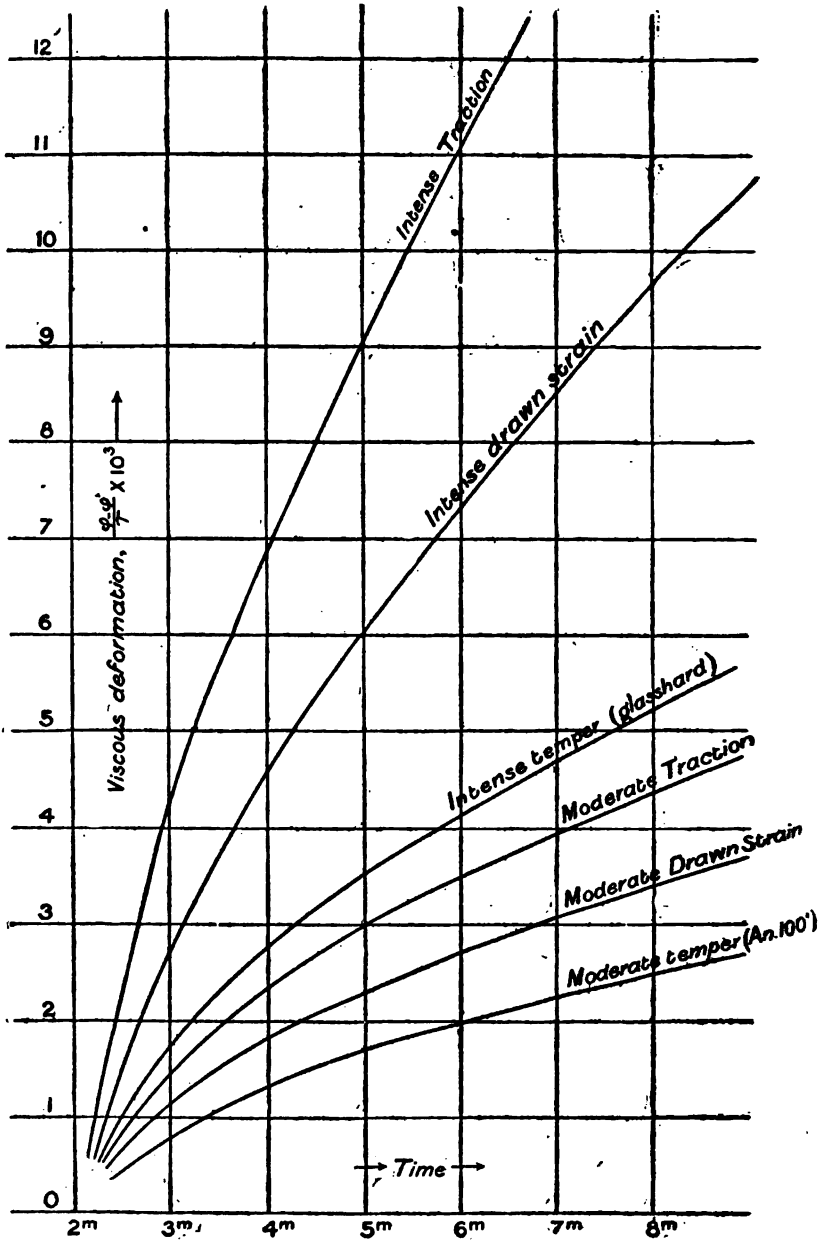


Fig. 2.—Time variation of viscous deformation, in case of soft steel transformed by temper, drawn-strain, traction, and torsion, respectively. The abscissa represents the soft or unstrained wire.

perature in question. The presence of carbon (steel) and rapid cooling is specially favorable to the production of β iron, and the presence of

Digitized by Google

this substance manifests itself in the resulting hardness of the metal. Now it is to be observed that the above observation on the similarity of viscous effects of all kinds of strain, whether tempered or mechanically applied, is in harmony with Osmond's theory. Again, the acknowledged instability of β iron at ordinary temperatures supplies the requisite unstable configurations in virtue of which, following Maxwell's theory, viscosity is reduced. This theory of Osmond, however, either proves too much or it is a suggestive working hypothesis relative to the behavior of other metals. For the results of Streintz, Tomlinson, and myself, cited above, show that in most if not all metals viscosity is reduced by the presence of marked intensity of mechanical strains. Certainly metals are capable of being hardened by traction, the draw plate, torsion, etc., although no phenomenon corresponding to Gore's phenomenon in iron has been observed. Osmond's theory of a change of molecule of iron by mechanical action therefore calls for experiments relative to the definite discovery of the α and β varieties of metals other than iron, nickel, and a few more, before the standpoint taken can be maintained.

An important inquiry is thus suggested which would lead ulteriorly to a test of Osmond's theory: It is to be found whether the maximum of drawn strain which the wire of a given metal can retain is (cæt. par.) a function of the viscosity of the metal; or whether the strain retained is largely independent of viscosity and subject to other conditions. In the last case retention would be conditioned by a chemical mechanism, and Osmond's theory would therefore be substantiated at once.

I may state in concluding that Osmond's views are not wholly new, having been suggested in their general bearings in a remarkable thermoelectric investigation by F. Braun.[1]

[1] F. Braun: Phil. Mag. (5), vol. 19, 1885, p. 503, § 8.

Digitized by Google

CHAPTER II.

THE TWO SPECIES OF MOLECULAR BREAK-UP WHICH PROMOTE VISCOUS DEFORMATION.

INTRODUCTORY.

6. Following the argument which underlies Maxwell's theory of solid viscosity experimentally, I was obliged to take cognizance of two causes which promote viscous deformation in solids.[1] For any structure will give way under impressed conditions of stress, as a whole or in part, because either the cements or the bricks are insufficiently strong to withstand it. Similarly the underlying cause of viscous motion is either such structural change in which groups of molecules pass without loss of identity from an initial to a final configuration, or it is a break-up superinduced by the disintegration of one or more molecules of each group. Whichever the change may be, it must, from the nature of the problem in general, be distributed uniformly throughout the mass of the solid (§ 14). Even without stress the said change may result from secular subsidence. Moreover it is conceivable that molecular disintegration may occur in such a way as to elude detection.

Now I have since been able to prove experimentally that in glass-hard steel a change of the viscous quality may be obtained as the result of at least *two* distinct kinds of structural change, probably as the result of the two kinds of break-up in question. The present chapter purposes to show this by aid of the phenomena of accommodation, or motional annealing, as they may be called more uniformly in keeping with the following work.

MOTIONAL ANNEALING DEFINED.

7. The term annealing or tempering, in its most general sense, refers to a process by which strained solid structure, whether maintained by mechanical or chemical causes, is changed to isotropic structure. In viscosity, inasmuch as strained structure is ultimately accompanied by molecular instability, annealing is a process by which viscosity is increased; and from this point of view annealing need have no direct reference to exposure to temperature. Hence I have designated by the term motional annealing all such forced molecular motion to and fro, in virtue of which the molecules of a thoroughly soft solid are brought into new relations to each other, to the effect that viscosity is increased at

[1] Phil. Mag., November, 1888.

Digitized by Google

the expense of the motionally less stable configurations of the soft solid. There may appear to be some incongruity in the term, inasmuch as the solid motionally acted on always experiences strain; it is not the strain, however, but the *increment of viscosity* of the solid, to which the term refers.[1]

Again, in order that a solid may be motionally annealed the mechanical treatment (torsion, traction, etc.) must be applied *below* a certain critical limit of intensity. Otherwise this treatment introduces its own specific instability; and in proportion as stress is indefinitely increased the viscosity of the solid may now be reduced in any measure. Further justification of the term is to be given in §§ 11, 14. At present it is more expedient to indicate the points of crucial difference between motional annealing and thermal annealing in their effect on steel in the glass-hard state.

STRAIN, ELECTRIC RESISTANCE, AND VISCOSITY.

8. When glass-hard steel is annealed at 100° the effect is a decided increase of viscosity amounting to almost one-half of the total viscous interval, hard-soft.[2] This marked increment of viscosity is accompanied by an equally striking electrical effect.[3] For it has been shown that the specific resistance of hard steel diminishes as much as 15 per cent as the result of annealing at 100°. Finally, since the electrical effect is a sufficient indication of the changes of volume (decrement) and of carburation, it appears conclusively that the underlying cause of the increase of viscosity here in question is a disintegration of the unstable carbide molecule of steel.

TEMPER, ELECTRIC RESISTANCE, AND VISCOSITY.

9. Again, an increment of the viscosity of glass-hard steel comparable in magnitude with that of annealing at 100° may be obtained without heat. It is merely necessary, for instance, to apply to the glass-hard wire large enough rates of twist, a sufficient number of times alternately, in opposite directions. This method of increasing viscosity has no electrical concomitant comparable with the electrical effect of § 8. Hence the underlying cause of the observed increase of viscosity in this case is probably not a disintegration of the carbide molecule of steel, or, at least, a disintegration quite unlike that of the foregoing instance.

DATA RELATIVE TO TEMPER, ELECTRIC RESISTANCE, AND VISCOSITY.

10. In the following tables (7 and 8) I give the data necessary to substantiate § 9. The method[4] of experiment being identical with the

[1] Phil. Mag., 5th ser., vol. 26, 1888, pp. 199 to 203.

[2] Am. Jour. Sci., 3d ser., vol. 33, 1887, p. 26; Phil. Mag., 5th ser., vol. 26, 1888, p. 188, et seq.

[3] Bull. U. S. Geological Survey, No. 14, p. 49, 1885.

[4] Phil. Mag., 5th ser., vol. 26, 1888, pp. 189 to 191. The use of differential methods premises that the viscous deformations of all the wires to be compared are similar time functions. That this is the case must be verified preliminarily by some absolute method.

one described in verifying § 8, I need only to call to mind here that my normal steel wire (maximum viscosity) and the fresh glass-hard wire (minimum viscosity) were countertwisted; that the ends of the vertical system were fixed, and a mirror-index placed near the middle, at the junction of the two wires.[1] Cf. Fig. 1, § 3. Table 1 contains the results for viscosity, both wires being at the same temperature θ. The impressed rate of twist is given in radians under τ, and the permanent torsion observed at the close of each experiment under $2(\varphi + \varphi')$. Since the lower end of the system was twisted 360°, $\tau + 2(\varphi + \varphi') = 2\pi/L$, where L is the length of the two wires. Finally, $(\varphi - \varphi')/\tau$ is the viscous motion at the index, per unit of τ, per unit of L, at the time specified. In other words, 2φ and $2\varphi'$ refer to the hard and the soft wires, respectively, and denote angular viscous motion of one right section relatively to another, when their distance apart is 1 cm. of length of wire. $(\varphi - \varphi')/\tau$ need not be independent of τ. (§ 13.)

Table 7 indicates that the wires were twisted eight times alternately in opposite directions. Before and after each series of viscous measurements in Table 7 the resistance of the glass-hard wire was measured by a special device utilizing Matthiessen and Hoskin's method. These results are given in Table 8, where r_t is the observed resistance in microhms, $\triangle r_t$ the variation from the final value, $r_t = 39500$.

TABLE 7.—*Viscous effect of motional annealing. Glass-hard steel.*

$\theta = 29$. L = 30 cm. + 30 cm. Diameter of wires, $2\rho = \cdot 081$ cm.

Twist No.	$\frac{\tau}{2(\phi+\phi')}$	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$	Twist No.	$\frac{\tau}{2(\phi+\phi')}$	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$
		h. m.				h. m.	
1.	+·0992	2 25		5.	+·1021	3 40	
		30	+ ·00			42	+ ·00
		32	·94			44	·68
		35	1·99			47	1·38
		38	2·79		+·0026	52	2·19
	+·0055	46	4·45				
2.	—·0983	2 49		6.	—·1018	3 55	
		51	— ·00			57	— ·00
		53	—1·95			59	— ·74
		56	—3·97			62	—1·44
	—·0064	63	—5·93		—·0029	67	—2·39
3.	+·1021	3 07		7.	+·1018	4 09	
		09	+ ·00			11	·00
		11	1·01			13	·64
		14	1·99			16	1·28
	+·0026	21	3·36		+·0029	20	1·89
4.	—·1021	3 24		8.	—·1018	4 23	
		27	— ·00			25	— ·00
		29	— ·91			27	— ·64
		32	—1·85			30	—1·28
	—·0026	37	—3·06		—·0029	37	—2·32

[1] See Bull. U. S. Geol. Survey No. 73, 1891, pl. I, p. 54.

Digitized by Google

TABLE 8.—*Electrical effect of motional annealing.*

Glass-hard steel, $2\rho = .081$ cm.

Twist No.	τ	r_t	Δr_t	Twist No.	τ	r_t	Δr_t
0.	0	39550	+ 50	5.	−·102	39560	+60
1.	−·099	39380	−120	6.	+·102	39530	+30
2.	+·098	39350	−150	7.	−·102	39500	+00
3.	−·102	39570	+ 70	8.	+·102	39510	+10
4.	+·102	39430	− 70				

DISCUSSION OF RESULTS.

11. The results of Table 7 are in excellent accord with my earlier data; and the oscillatory march of the viscous increment can be represented in the same way. If the tangents be constructed at the same time-point, in each of the curves of Table 7 there appears to be some similarity between the march of these results ($\Sigma(\varphi-\varphi')/\tau$) and the corresponding march of r_t in Table 8. But interpreted by the data of § 7, this similarity is only qualitative in kind. In other words, whereas the increment of viscosity due to successive alternations of twist is decidedly greater than one-half of the increment of viscosity due to annealing glass-hard steel at 100°, it appears that the electrical effect in the first instance (motional annealing) is practically negligible in comparison with the electrical effect of thermal annealing. In Table 8 the total interval of variation of Δr_t is about one-half per cent of r_t; on the other hand, the variation of r_t due to annealing at 100° is from 10 per cent upward. It follows that in glass-hard steel there are two distinct ways in which viscosity may be appreciably increased, a result corroborating §§ 8, 9. Again, if the possibilities of viscous motion are to be fully given, it is essential to postulate groups of atoms, as well as the somewhat less definite groups of molecules, both varying in degrees of stability from point to point of the solid mass. Hence slight positional change of the elements of the atomic configurations, or of the molecular configurations, due either to stress not exceeding a critical value or to mere secular subsidence, must in general involve an augmentation of the viscous quality.

DATA FOR CYCLIC TWISTING.

12. Having arrived at this result I desire to inquire somewhat more in detail into the viscous relations of the motional effect, §§ 9, 10. This is attempted in Table 9, in which torsional stress is applied cyclically. The viscous behavior is studied at each of these successive stages of increase or decrease, as shown in the first column, τ, of the table. As before, the length of the system of two wires, $L = l + l' = 30$ cm. + 30 cm.; diameter, $2\rho = .081$ cm. The final column, $\Sigma(\varphi-\varphi')$, being the detorsion from the beginning to the end of the first minute after

Digitized by Google

twisting, may be taken as an index of the rate of deformation. In the first and second cycles twist is imparted positively; in the third cycle negatively. To follow the sequence of observations it is sufficient to consult the time column.

TABLE 9.—*Viscous deformation in case of cyclic twisting.*

FIRST CYCLE.

Twist increasing.					Twist decreasing.			
Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\frac{\phi-\phi'}{\tau}\times10^3$	$\Delta(\phi-\phi')\times10^6$	Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\Delta(\phi-\phi')\times10^6$
						h. m.		
·000					·000	12 31	.....	—10
						32	0	
						33	— 10	
						34	— 20	
						35	— 27	
						1 18	—107	
						30	—120	
	h. m.							
·009	10 36	.....	.....	3	·009	12 26	.....	— 8
	37	0	·0			27	0	
	38	3	1·1			28	— 8	
	39	5	1·5			29	— 15	
	40	6	1·9			30	— 21	
·017	10 41	.....	.....	9	·017	12 21	.....	— 5
	42	0	·0			22	0	
	43	9	1·4			23	— 5	
	44	15	2·8			24	— 12	
	45	20	3·2			25	— 17	
·026	10 46	.....	.....	14	·026	12 16	.....	— 7
	47	0	·0			17	— 0	
	48	14	1.5			18	— 7	
	49	23	2·5			19	— 12	
	50	27	2·8			20	— 15	
·035	10 51				·035	12 11	.....	— 7
	52	0				12	0	
	53	31				13	— 7	
	54	51				14	— 13	
	55	67				15	— 15	
·043	10 56				·043	12 06	.....	— 5
	57	0				07	0	
	58	45				08	— 5	
	59	77				09	— 8	
	60	100				10	— 13	
·052	11 01				·052	12 01	.....	— 3
	02	0				02	0	
	03	36				03	— 3	
	04	69				04	— 9	
	05	103				05	— 11	

Digitized by Google

TABLE 9.—*Viscous deformation in case of cyclic twisting*—Continued.

FIRST CYCLE—Continued.

Twist increasing.					Twist decreasing.			
Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\frac{\phi-\phi'}{\tau}\times10^3$	$\Delta(\phi-\phi')\times10^5$	Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\Delta(\phi-\phi')\times10^6$
	h. m.					*h. m.*		
·061	11 06				·061	11 56	.....	— 7
	07	0				57	0	
	08	60				58	— 7	
	09	100				59	— 7	
	10	133				60	— 9	
·070	11 11	.....	.....	97	·070	11 51	.....	— 5
	12	0	·0			52	0	
	13	97	3·8			53	— 5	
	14	153	6·1			54	— 5	
	15	207	8·2			55	— 5	
·078	11 16	.....	.....	100	·078	11 46	.....	— 2
	17	0	·0			47	0	
	18	100	3·5			48	— 2	
	19	167	5·9			49	— 2	
	20	237	8·3			50	— 1	
·087	11 21	.....	.....	117	·087	11 41	.....	+ 3
	22	0	·0			42	0	
	23	117	3·7			43	+ 3	
	24	197	6·3			44	+ 7	
	25	263	8·3			45	+ 10	
·096	11 26	.....	.....	137	·096	11 36	.....	+ 8
	27	0	·0			37	0	
	28	137	3·9			38	+ 8	
	29	233	6·8			39	+ 21	
	30	307	8·9			40	+ 31	
·105	11 31	.....	.....	167				
	32	0	·0					
	33	167	4·4					
	34	280	7·4					
	35	397	9·6					

Digitized by Google

TABLE 9.—*Viscous deformation in case of cyclic twisting*—Continued.

SECOND CYCLE.

Twist increasing.					Twist decreasing.			
Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\frac{\phi-\phi'}{\tau}\times10^3$	$\Delta(\phi-\phi')\times10^6$	Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\Delta(\phi-\phi')\times10^6$
						h. m.		
·0					·0	2 26	.....	— 9
						27	— 0	
						28	— 9	
						29	— 17	
						30	— 23	
	h. m.							
·017	1 31	.....	.....		·017	2 21	.....	—12
	32	0	·0			22	— 0	
	33	5	·7			23	— 12	
	34	7	1·2			24	— 19	
	35	11	1·8			25	— 25	
·035	1 36	.....	.....	7	·035	2 16	.....	— 5
	37	0	·0			17	— 0	
	38	7	·5			18	— 5	
	39	13	1·1			19	— 10	
	40	15	1·2			20	— 15	
·052	1 41	.....	.....	7	·052	2 11	.....	— 9
	42	0	·0			12	— 0	
	43	7	·3			13	— 9	
	44	10	·5			14	— 11	
	45	17	·9			15	— 14	
·070	1 46	.....	.....	7	·070	2 06	.....	— 7
	47	0	·0			07	— 0	
	48	7	·3			08	— 7	
	49	19	·7			09	— 7	
	50	30	1·2			10	— 7	
·087	1 51	.....	.....	15	·087	2 01	.....	— 2
	52	0	·0			02		
	53	15	·5			03	— 0	
	54	30	·9			04	— 2	
	55	41	1·3			05	— 4	
·105	1 56	.....	.....	67				
	57	0	·0					
	58	67	1·0					
	59	120	3·2					
	60	170	4·5					

Digitized by Google

TABLE 9.—*Viscous deformation in case of cyclic twisting*—Continued.

THIRD CYCLE.—TWIST IN OPPOSITE DIRECTION.

Twist increasing.					Twist decreasing.			
Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\frac{\phi-\phi'}{\tau}\times10^3$	$\Delta(\phi-\phi')\times10^6$	Rate of twist, τ	Time.	$(\phi-\phi')\times10^6$	$\Delta(\phi-\phi')\times10^6$
	h. m.					h. m.		
·017	3 24	.....	.....	12	·0	4 17	.....	−28
	25	0	·0			18	− 0	
	26	12	1·9			19	− 28	
	27	19	3·0			20	− 45	
	28	25	3·9			21	− 63	
	29	28	4·6					
.035	3 30	.....	.....	13				
	31	0	·0					
	32	13	1·1					
	33	32	2·5					
	34	37	2·9					
·052	3 35	.....	.....	43				
	36	0	·0					
	37	43	2·3					
	38	77	4·1					
	39	103	5·5					
·070	3 40	.....	.....	97	·070	3 50	.....	− 1
	41	0	·0			51	− 0	
	42	97	3·8			52	− 1	
	43	163	6·5			53	− 1	
	44	213	8·5			54	+ 2	
·087	3 45	.....	.....	147	·087	4 00	.....	+ 5
	46	0	·0			01	0	
	47	147	4·7			02	+ 5	
	48	240	7·6			03	+ 14	
	49	307	9·8			04	+ 23	
·096	3 55	.....	.....	117	·096	4 10	.....	0
	56	0	·0			11	+ 0	
	57	117	3·4			12	+ 0	
	58	207	6·0			13	+ 10	
	59	273	7·9			14	+ 27	
·105	4 05	.....	.....	135				
	06	0	·0					
	07	135	3·6					
	08	240	6·4					
	09	313	8·3					

DISCUSSION OF RESULTS OF CYCLIC TWISTING.

13. *The marked feature.*—The first result given by these data is obtained by comparing $\varphi-\varphi'$ and $(\varphi-\varphi')/\tau$, showing that the latter quantity is not independent of τ. Nor can it be asserted that the change of $(\varphi-\varphi')/\tau$ with increasing τ is retarded. It follows that comparable values of $(\varphi-\varphi')/\tau$ are only obtained by keeping τ nearly constant, as has been done in all my experiments.

Digitized by Google

Again, the large variations of $\Delta(\varphi-\varphi')$ in the direct or stress-increasing phase of the cycles, as compared with the corresponding variations in the retrograde or stress-decreasing phase of the cycles, together with a repetition of the whole phenomenon on a smaller scale for succeeding cycles of the same sign, are features of these experiments. When the sign of the twist is reversed, cycles which exceed the original one in magnitude are obtained. These in their turn dwindle on repetition of like signs of τ. Finally, the influence of residual action in case of retrograde cycles appears more clearly in proportion as stress approaches zero. On the other hand, the circumflex contours of the earlier retrograde curves (τ decreasing from ·105) is not a mere error of observation, but results from superposition of direct and residual phenomena. This is specially marked in the third cycle, where stress, after $\tau=$·087, was applied in a zigzag way, viz:

$$\tau \times 10^3 = 87, 70, 96, 87, 105, 96.$$

14. *Analogy with thermal annealing.*—The clue for the interpretation of the above complex phenomena as a whole is suggested by the data for $\Delta(\varphi-\varphi')$. It then appears that the viscous behaviour of the wires is intimately connected with the amount of permanent set imparted during the period of action of stress. From this point of view the phenomena become not only strikingly analogous to thermal annealing in case of temper, but of special importance as regards their bearing on Maxwell's theory. The following description[1] applies, mutatis mutandis, to both classes of phenomena:

(1) The viscous deformation (annealing effect) of any stress (temperature) acting on glass-hard steel increases gradually at a rate diminishing through infinite time; diminishing very slowly in case of low stress (temperature); diminishing very rapidly at first and then again slowly in case of high stress (temperature); so that the limit of permanent deformation is approached asymptotically.

(2) The ultimate viscous deformation (annealing effect) of any stress τ (temperature t), is independent of preexisting effects of the stress τ' (temperature t'), and is not influenced by subsequent application of stress τ' (temperature t'), provided $\tau>\tau'$ ($t>t'$). In case of incomplete deformation (partial annealing) induced by stress τ (temperature t). this law applies more fully as the ultimate effect of τ (t) is more nearly reached. Again, the effect of τ' succeeding τ (t' succeeding t) is more nearly nil as the effect of $\tau>\tau'$ ($t>t'$) approaches completeness.

To discern the cause of this detailed analogy it is sufficient to call to mind, (1) that in thermal annealing viscous deformation is produced by thermal diminution of viscosity under conditions of the initially given stress stored up in the tempered solid; in motional annealing by increase of the mechanical stress applied from without under conditions of initially given viscosity. Finally, (2) the configurations, molecular

[1] Cf. Phil. Mag., 5th ser., vol. 26, 1888, p. 214.

Digitized by Google

or atomic, which just break up under the action of stress τ or temperature t, respectively, are necessarily limited by a higher order of stability, and are greater in number than those just surviving under less intense conditions of stress or temperature. This is the crucial feature of the analogy. However unlike the instabilities may be in the two cases of motional and of thermal annealing, however unlike the treatment to which they are here respectively subjected, its effect in *modifying the occurrence* of instability is similar, and hence the similarity of viscous results.

So far as I have observed, however, residual phenomena are absent in thermal annealing of glass-hard steel, and this is a point of difference between the break-up of atomic groups and molecular groups. The former are not reconstructed. Again, in motional annealing for increasing rates of twist, thick wires show viscous deformation at earlier dates than thin wires. The break-up commences at the external surface, where stress is most intense, and proceeds thence to the axis, where stress is least. The history of motional annealing is therefore essentially dependent on the dimensions of the deformed wire and varies for different values of radius. I pointed out[1] that in soft iron the limits of torsional resilience were reached when the obliquity of the external fiber (shear) somewhat exceeds .003 radians. Finally, the ultimate annealing effect (time $= \infty$) of any temperature t acting on glass-hard steel increases at a retarded rate with temperature, and practically reaches the limit of variation below 350°. In case of motional annealing stress may be applied in any degree from without, and increasing effects obtained limited only by the given degrees of resilience or of brittleness. Nevertheless, if the wire admits of permanent set, the analogy pursued may be pushed even to this extreme detail. For, just as in the case of thermal annealing above 350°, no further marked effects are produced, because the intensity of stored stress is invariably below the value of viscosity; so in case of motional annealing, when stress surpasses the limits of resilience, further increment of marked consequence is no longer elastically retained.

[1] Am. Jour. Sci., vol. 34, 1887, p. 183.

Digitized by Google

CHAPTER III.

THE EFFECT OF MECHANICAL STRAIN ON THE CARBURATION OF STEEL.

INTRODUCTORY.

15. *Drowne's experiments.*—I shall, in this chapter, endeavor to discuss the nature of some shortcomings of the present methods for the estimation of uncombined carbon in addition to the subject matter of the superscript. Among earlier investigators Dr. Thomas Drowne[1] has made similar observation with reference to cast iron. The stimulus of Drowne's work was a remark of Bell's, stating that white and gray pig iron differ only in the magnitude of graphitic crystals contained, which crystals are fine grained in white pig, and coarse grained in gray pig. To disprove this assertion Drowne cast a sample of iron in a chill mold,[2] thus obtaining both the white and the gray variety. Analyses showed that while these two parts of the same casting did not differ much in total carbon, the free carbon in the gray iron was more than twice as great in amount as the free carbon in the white iron. He thus obtained strong evidence against Bell's statement. Drowne then proceeded to vary the method of treatment by varying the solvent and by boiling. He infers that the carbide is not decomposed except by boiling, and accentuates the crudeness of the analytical methods.

16. *The present method.*—The above pages have clearly shown that the underlying cause of viscous deformation is either a break-up of atomic or of molecular configuration. The former phenomenon admits of direct proof and does occur in glass-hard steel. The molecular break-up is less easily verifiable, and can not be as clearly defined as the other. I have therefore been tempted to question whether, even in the case of viscous deformation induced by mechanical strains, the underlying break-up is a mere rearrangement of molecules. (Cf. § 9.)

Among the more promising methods for deciding this question, the plan adopted in the discussion of annealing phenomena[3] suggests itself. An exceedingly intimate intermixture of carbon and iron is here presented. Indeed Matthiessen considered it a solidified solution or mix-

[1] Drowne: Trans. Am. Inst. Mining Engineers, vol. 3, 1874–'75, pp. 41–44.

[2] I may refer here to a similar experiment of Karsten's (Eisenhüttenkunde, Bd. I, 3 Aufl., 1841, p. 581, et seq.) from which the distinction between combined and uncombined carbon was originally derived.

[3] Barus: Bull. U. S. Geol. Survey, No. 73, Chap. III, 1891.

Digitized by Google

tures of these. Hence the possibility of chemical changes of configuration superinduced by mechanical stress (wire-pulling, torsion, flexure, traction, compression) applied from without, is favorably open to experiment. Put in its simplest form, the problem is a determination of the variation of the amount of the uncombined carbon in steel, produced by stress; for it may be plausibly argued, I think, that such disintegration of molecule as is here in question could hardly take place without the accompaniment of a carburation effect.

METHOD OF EXPERIMENT.

17. The method of procedure, apart from its extreme tedium, is sufficiently simple. A soft wire of proper length is cut into halves, one of which is dissolved without further treatment, the other drawn down to as small a diameter as feasible and also dissolved. The two samples are then tested for uncombined carbon. I used the customary process described by Blair in its most complete form. The samples were dissolved in cold dilute acid, then boiled, after which the carbon was collected on Gooch's asbestos filter, duly washed with dilute HCL and hot water, KOH, alcohol and ether. It was thereupon dried at a temperature of at least 160° for a sufficient time, cooled in a desiccator, and the difference in weight of the Gooch crucible before and after ignition in oxygen estimated as carbon. This is not as accurate a process as the regular combustion method usually prescribed. But it is far more expeditious; and the errors made in weighing carbon directly are of very much smaller moment than the solution and other errors which I will point out below. Indeed the validity of the whole method stands seriously in question, in a number of fundamental particulars; and so long as these have not been surely cleared away, refinements of carbon measurement are obviously absurd.

RESULTS OBTAINED.

18. My results are given in the following Table 10. To understand them fully, introductory remarks as to the structure of the soft steel used in each case are essential. In my first experiments (rods Nos. 1 and 2 for instance), I drew down the whole wire; then I softened one-half of it after drawing, by annealing at red heat *in air*. On dissolving, the drawn wires were very much more intensely attacked than the freshly softened wires; so that the beaker containing drawn wires is turbid and black with carbon before the other hardly shows traces of carbon precipitate. This result is exceedingly striking and uniform, and I at first inferred that the effect of drawing is necessarily a transformation of carbon in steel from the combined to the uncombined state. And yet this conclusion, as I afterwards found, does not at all follow. The effect of annealing at red heat on the carbon in the steel varies enormously with the details of the method. In other words, steels of a given kind and nominally soft, may nevertheless differ remarkably in internal struc-

Digitized by Google

ture. If we start with soft steel, annealed by the commercial method of excessively slow cooling, and then draw the wires down, it can not be assumed that the part of the drawn wire which is annealed at red heat and cooled in air after drawing, is identical with the wire before drawing. Indeed, since the rate of cooling increases as the diameter decreases, it follows that two wires annealed at red heat in air must differ in degrees of softness and carburation even if all other conditions are the same. I desire to emphasize this point for it indicates the first difficulty with which I had to contend.

TABLES.

19. In the Table I have, therefore, inserted the treatment and temper of the wire before drawing in the wire plate, as well as after drawing. The radius ρ of the wire is also given for each case.

M is the mass of steel dissolved, in grammes. A larger amount would have been desirable, but the rods of best Stubb's steel come in short lengths (33^{cm}), and as the drawing of each new length nearly doubles the labor, I did not care to operate upon greater masses (M) of steel. The carbon contained in the M grammes in question is given under m, also in grammes, and the final columns contain the values of m / M.

Excepting numbers 27 and 28, the first thirty-four measurements were made with a view to testing the steel; the next twenty-one (numbers 35 to 56) chiefly with a view toward testing the method. In the final measurements, the steel again is chiefly considered.

TABLE 10.—*Graphitic carbon in soft and in drawn steel.*

[S, annealed from red heat, with very slow cooling (commercial). SA, heated to redness and cooled in air. GH, glass-hard. An, annealed at 500°. Dr, fresh drawn, usually from diameter $= 2\rho = 0{\cdot}13^{cm}$ to $2\rho = 0{\cdot}08^{cm}$.]

Before drawing.			Before dissolving.		M	$m \times 10^3$	$\frac{m}{M} \times 10^3$	No.
Original condition.	Final condition.	$2\rho \times 10^3$	Condition.	$2\rho \times 10^3$				
S	S	130	Dr	80	3·10	18·3	5·9	1
S	S	130	SA	80	3·16	15·4	4·9	2
S	S	130	Dr	80	3·17	15·9	(?)5·0	3
S	S	130	An. 1^h	80	3·14	17·4	5·5	4
S	S	130	An. 1½^h	80	2·30	16·5	5·5	5
S	S	130	SA	80	2·91	lost	.....	6
S	SA	130	Dr	80	3·04	17·2	5·6	7
S	SA	130	SA	80	2·98	18·0	6·0	8
GH	SA	130	SA	130	3·15	14·9	4·7	9
GH	SA	130	Dr	90	2·96	18·2	6·1	10
S	S	130	S	130	3·25	27·1	8·3	11
S	SA	130	SA	130	3·21	22·2	6·9	12
GH	SA	130	SA	130	3·17	16·7	5·3	13
GH	SA	130	Dr	80	2·96	17·4	5·9	14
GH	SA	130	SA	130	3·22	19·7	6·1	15
GH	SA	130	Dr	80	2·74	14·9	5·4	16

Digitized by Google

TABLE 10.—*Graphitic carbon in soft and in drawn steel*—Continued.

[S, annealed from red heat, with very slow cooling (commercial). SA, heated to redness and cooled in air. GH, glass-hard. An, annealed at 500°. Dr, fresh drawn, usually from diameter $= 2\rho =$ 0·13^{cm} to $2\rho =$ 0·08^{cm}.]

Before drawing.			Before dissolving.		M	$m\times10^3$	$\frac{m}{M}\times10^3$	No.
Original condition.	Final condition.	$2\rho\times10^3$	Condition.	$2\rho\times10^3$				
S	SA	130	SA	130	3·25	24·2	7·4	17
S	SA	130	Dr	80	2·94	15·7	5·3	18
S	S	130	S	130	3·28	24·6	7·5	19
S	S	130	Dr	80	3·07	19·5	6·3	20
S	S	130	S	130	3·26	23·0	7·0	21
S	S	130	Dr	80	3·08	19·5	6·3	22
S	S	140	S	140	3·95	28·6	7·2	23
S	S	140	Dr	80	3·34	29·0	8·7	24
S	S	140	S	140	4·00	28·6	7·1	25
S	S	140	Dr	80	3·48	35·3	10·1	26
S*	S	140	S	140	4·16	4·6	1·1	27
S*	S	140	Dr	80	3·05	5·8	1·9	28
S	S	140	S	140	4·36	29·7	6·8	29
S	S	140	Dr	80	3·54	21·8	6·1	30
GH	SA	130	SA	130	3·23	16·6	5·1	31
GH	SA	130	Dr	90	2·82	20·7	7·3	32
GH	SA	130	SA	130	3·25	16·7	5·1	33
GH	SA	130	Dr	90	2·61	15·4	5·9	34
(†)			S	120	2·29	14·7	6·4	35
(‡)			S	120	2·25	13·6	6·0	37
(†)			S	120	2·27	14·6	6·4	36
(‡)			S	120	2·22	11·5	5·2	38
	HCl	20%	S	120	3·10	25·3	8·1	39
	HCl	22%	S	120	3·25	24·2	7·4	40
	HCl	15%	S	120	3·13	27·0	8·6	41
	HCl (conc)	38%	S	120	3·25	32·6	10·0	42
Beaker	HCl	25%	S	130	3·14	24·3	7·7	43
Erl. flask, etc	HCl	25%	S	130	3·21	9·9	3·1	44
Erl. flask, etc	HCl	12%	S	130	3.13	23·6	7·5	45
Beaker, boiling	HCl	25%	S	130	3·20	1·5	0·5	46
Beaker, boiling	HCl	10%	S	130	.....	0·0	0·0	46a
S	S	130	S	80	2·37	15·4	6·5	§47
S	S	130	Dr	80	2·39	16·8	7·0	‖48
Dissolved in a beaker under identical conditions of concentration and temperature.								
	S	130	S	130	2·59	18·3	7·1	49
	S	130	Dr	80	2·58	19·6	7·6	50
	S	130	S	130	2·48	22·9	9·2	51
	S	130	Dr	80	2·48	17.2	6·9	52

* Dissolved in boiling acid, sp. gr., 1·15, 30% HCL.
† Dissolved in cold acid, sp. gr., 1·15, 30% HCL.
‡ Dissolved in dilute cold acid, sp. gr., 1·07, 15% HCL.
§ Dissolved down.
‖ Drawn down.

Digitized by Google

TABLE 10.—*Graphitic carbon in soft and drawn steel*—Continued.

[S, annealed from red heat, with very slow cooling (commercial). SA, heated to redness and cooled in air. GH, glass-hard. An, annealed at 500°. Dr. fresh drawn, usually from diameter = $2\rho = 0{\cdot}13^{cm}$ to $2\rho = 0{\cdot}08^{cm}$.]

Dissolved under identical conditions in Erlenmeyer flask with Bunsen valve. Acid 1·13 at 24°. 60cc taken per 1 gr. iron.

Before drawing.			Before dissolving.		M	$m \times 10^3$	$\frac{m}{M} \times 10^3$	No.
Original condition.	Final condition.	$2\rho \times 10^3$	Condition.	$2\rho \times 10^3$				
	S	130	S	130	3·16	12·5	3·9	53
	S	130	Dr	80	1·77	8·2	4·6	54
	S	130	S	130	3·19	12·3	3·8	55
	S	130	Dr	80	2·21	6·9	3·1	56
GH	SA	130	SA	130	3·03	11·8	3·9	57
GH	SA	130	Dr	80	2·51	9·1	3·6	58
GH	SA	130	SA	130	3·19	11·3	3·5	59
GH	SA	130	Dr	80	2·82	6·6	2·3	60
	S	130	S	130	5·77	20·1	3·5	61
	S	130	Dr	80	5·46	6·3	1·1	62
	S	80	GH	80	4·35	.....	0·0	63
	S	80	An. 450 ...	80	3·50	4·2	1·2	64

DISCUSSION.

20. *Inconsistency of the results.*—To obtain a comprehensive survey over this large number of data, it is expedient to lay them down graphically. This can be done clearly by erecting perpendiculars equidistant, on the same base for each of the states S, SA, GHSA, Dr, Dr, SA, etc., and laying off the divers carburation data m along the vertical lines. Points belonging to the halves or other parts of the same wire are then connected by a line with an arrow indicating the direction of the operation. Thus, S → Dr would denote that one-half of the originally soft rod was drawn down, the remainder being left in the soft state.

It is well to commence with the rods Nos. 1 to 22, all of these being of the same kind of steel (diameter 130cm). It will be seen that the drawn wires here lie within a relatively narrow zone, whereas the soft wires are widely scattered. The diagram is such as to suggest very pointedly that the operation of drawing steel either precipitates or dissolves carbon according as the amount of free carbon in soft steel is less or greater than the quantity needful for the drawn state. Fortunately, however, I was induced to suspect an error in these data notwithstanding their general consistency and number; for the behavior of the couple Nos. 15 and 16, for instance, is anomalous. I may remark in passing that Nos. 7 and 8 showed the marked difference of rate of solution already referred to in § 18 Nos. 11, 12, and due to the resolution of carbon produced by annealing a thoroughly soft wire in air, etc. Nevertheless so remarkable a result was not to be rashly enunciated, and I therefore resolved to continue the experiments with steel of

Digitized by Google

another kind. Rods 23 to 30 were tested. The results here obtained were such as wholly to vitiate the inferences drawn from the first lot. At least the drawn samples now lie far apart, and away from the earlier drawn group, whereas the soft rods are more nearly identical. Hence it began to appear that the data in hand had no discernible meaning at all; that the differences of the carburation positions of the soft and drawn wire were the result of flaws in the method of chemical treatment. These adverse views are substantiated by Nos. 27 and 28, which were boiled during solution. The result is a sacrifice of all but one-fifth or less of the free carbon found after dissolving in cold acid. A few additional experiments, Nos. 31 to 34, made with the first steel wire, corroborate the remarks made relative to the deep-seated insufficiency of the method.

21. *Errors of the method.*—Having been obliged to come to these unfavorable conclusions I thought it desirable, in view of the importance of the results to be reached, to make some attempt in perfecting the method. The experiments 35 to 52 are made chiefly with this end in view. The sources of error are unfortunately so complex as to make the interpretation a problem of almost insuperable difficulty. There are at least six such sources to be considered, viz, temperature; the concentration of the solvent acid; the effect of solution in air, and in hydrogen; the rate of solution; the variations of structural density of the wire, etc.

22. *Temperature.*—Nos. 27 and 28, already given, and Nos. 46 and 46*a* show that at 100° nearly all the free carbon is removed during solution; and that this is the case moreover for acids of any reasonable strength (HCl, 12 % to 25 %). Hence, since the amount of free carbon obtained rapidly diminishes (cæt. par.) with increasing temperature, it follows that data for two samples are not comparable unless the temperature has remained constant throughout the whole interval of solution for each. Particularly does this apply in case of different weights.

23. *Concentration of acid.*—The strength of acid used is an item of even greater importance. This is shown by Nos. 35 to 45. In the first group of experiments, Nos. 35 to 38, the effect of concentration in increasing the amount of free carbon is already apparent. Experiments 39, 40, 41, 42, however, show this more convincingly. In case of concentrated acid (No. 42) nearly all the carbon in steel is precipitated during solution. In all such experiments, however, the time of solution is an essential consideration. I do not refer so much to the rate of solution as to the time of exposure of the liquid to air or other gases. In the present instance, No. 41, which dissolved very slowly in the dilute acid, has an exceptionally high position. To some extent the same influence may be present in No. 42, which also dissolved very slowly under the opposite conditions of very strong acid.

24. *Solution in air and in hydrogen.*—The large differences obtained

Digitized by Google

for these two cases are shown in Nos. 43 to 45, and in most of the experiments Nos. 49 to 62. The results here obtained are the most important of the present section, inasmuch as they indicate the probable nature of the error of the method and the steps necessary to perfect it. Comparing Nos. 43 and 44, it appears that the solution in hydrogen, i. e., in an Erlenmeyer flask provided with a Bunsen valve, is accompanied with a precipitation of less than one-half as much carbon as separates out under the ordinary conditions of solution in a covered beaker. If the acid be very dilute (No. 45) so that solution takes a very long time, then the effect of the Bunsen valve is nil. because it is not sufficiently tight. It follows from these data that the solution of soft steel is not generally a simple phenomenon; that an *oxidizable* hydrocarbon or similar compound escapes, which in presence of air or available oxygen deposits carbon by secondary decomposition. This inference is conclusively substantiated by the beaker series, Nos. 49 to 52, as compared with the flask series (Bunsen valve), Nos. 53 to 56. When solution takes place in a covered beaker, the carbon precipitate, besides being in larger amount, is different in character from the flask precipitate. The latter is heavy and graphitic; the former contain as very light suspended admixture, which it is difficult to wash down in the Gooch crucible.

25. *Rate of solution.*—Whether the rate of solution has any direct influence on the carbon deposited, I am unable to affirm with certainty. If it does, the effect is probably small; for instance, solution in concentrated HCl (No. 42) takes place relatively slowly, as does also solution in dilute acid (41). But the large amount of carbon found is probably due to atmospheric influence. Nevertheless, in view of the large thermal effect already pointed out, it can not be asserted that the rate of solution is a negligible factor.

26. *Structural density.*—In experiments Nos. 47 and 48 one sample was drawn down and the other diminished in diameter by solution, whereupon both were identically dissolved for analysis. There is no difference in free carbon discernible. Inasmuch, however, as the drawn strain is characterized by superficial condensation accompanied by core dilatation, I was induced to ascribe the differences in the values of m for rods Nos. 57 to 62 to some such cause; for here the experiments were made in a way to take advantage of all refinements of research. Yet the low value of No. 62 (corroborated) defies explanation. Had the precipitate been too large it might have been ascribable to an imperfect valve.

27. *Summary.*—Summarizing the above, I conclude that such carburation differences as appear in the above data are to be looked upon as the result of secondary decomposition. In the case of soft steel the solution in HCl produces an unstable carbide which, under the influence of an oxidizing agency, splits up with a deposition of carbon. The precipitate found in such cases is no indication at all of the carbon actually

Digitized by Google

free in steel. So far as the above results go, the effect of mechanical strain on the carburation of steel is not demonstrable; at least all molecular disintegration superinduced by mechanical means is negligible in comparison with the present errors of the method for estimating free carbon. It might be inferred that the qualitative difference in the carburations of glass-hard and of soft steel is also to be suspected. In this case, however, sharp distinction may be made as follows: In glass-hard steel it is impossible by any rational method of treatment to obtain precipitation of free carbon out of the solution. In soft steel it is equally impossible by the same rational method of treatment to dissolve without a free-carbon deposit. For intermediate tempers proportionate amounts are deposited (cf. Nos. 63 and 64, which close the analyses).

Finally, to distinguish between the different kinds of carburation empirically, two methods suggest themselves: Solution may be made either in a current of hydrogen in hermetically-closed vessels, under identical conditions of concentration (grammes HCl, per gramme water, per gramme steel), and of temperature, etc., for all wires; or else in a current of oxygen under the same identical conditions. In the former case presumably only the free carbon in the steel is actually deposited. In the latter case (oxidation) the free carbon is definitely incremented by the deposition obtained from the oxidizable unstable carbide.

I took steps toward testing the first of these methods (solution in a current of hydrogen), but have thus far been prevented from pushing the question decisively to an issue.

28. ***Osmond's α and β iron.***—If the difference between steel hardened mechanically and the same steel soft is due to Osmond's α and β iron (cf. § 5), then the possibility of molecular change due to the mechanical treatment is beyond the province of the present method. It is well to bear this in mind. Carbon under certain conditions may be favorable to the stability of β iron, but it is not essential to its existence beyond a certain relative quantity. In view of these considerations the experiments of the next chapter are more pertinent to the subject of inquiry.

Digitized by Google

CHAPTER IV.

THE EFFECT OF STRAIN ON THE RATE OF SOLUTION OF STEEL.

INTRODUCTORY.

29. The difficulties encountered in the preceding section, in which the effect of strain on carburation is directly put to test, suggested a possible solution by indirect methods. It is well known that the effect of mechanical treatment, for instance, of rolling, drawing, etc., is apt to show itself in the structure of the metal when acted on by acids. The fiber of iron may thus be clearly exhibited; and even in cases of galvanic solution the surface often becomes furrowed and marked in a way indicative of definite structure. It appears, therefore, that some parts of the metal are more electropositive than others; and it does not seem improbable that homogeneous and strained metal may be distinguished by studying their respective rates of solution under given conditions.

METHOD.

30. Solution experiments of this kind are given in the following tables. The method of experiment is again simple. The weighed rods of known length are placed in a small tray made of narrow strips of hard rubber. Thus they can all be submerged or withdrawn from the acid at the same time. Some care was necessary as regards drying the samples before weighing. Having taken them out of the solution on the tray (this was # shaped, with the wires placed across either set of parallel bars or rubber strips are placed edge upward), the wires were submerged in water and then dried in an air bath at 100°. The bars of the tray were notched so as to avoid displacement of the wires. As they could be carried together, it was not necessary to touch them except with the forceps before weighing. This structure of the tray, moreover, is such as to allow free circulation of acid. The essential data to be noted are the temperatures of the acid and the weight and length of each rod before and after dipping. From this the radius for each case may be calculated. Two series of experiments must be made for each group of steel rods. It is first necessary to find the consecutive solution data in case of *homogeneous* wire gradually decreasing in thickness; with these data the corresponding results for wire *drawn down* from the original homogeneous wire may then be compared,

Digitized by Google

TABLES.

31. In Table 11 I give the results for three identical, nearly homogeneous steel wires, about 5^{cm} long and originally ·127^{cm} thick, submerged in dilute acid of a given kind, for consecutive intervals of time of one hour each. Here θ is the temperature of the acid; m the mass of the rod in grammes, r the radius, and Δr the consecutive decrement of radius due to solution. The progress of the experiment may be followed by consulting either M or r. Corrections are applied for the reduction of length due to solution.

In Table 12 data are given for drawn steel, the thickness of the individual wires varying between ·127^{cm} and ·084^{cm}. They are all drawn down from the same sample of soft steel, so that the larger thicknesses are soft, the thinner wires very resilient and brittle. All wires, Nos. 1 to 7, are submerged together; but variations of strength of acid, time, and temperature are the causes of differences of mass dissolved in successive solutions. From Table 11, however, the rates of solution for different thicknesses of homogeneous wire are known. Hence the behavior of the drawn wires during each solution can be tested. In Table 12, M', r', $\Delta r'$ denote the mass, radius, and variation of radius of the drawn wire, $\Delta r'$ being simply the difference between consecutive values of r before and after solution. Δr may therefore be interpolated from Table 11 by making the first term of $\Delta r'$ and Δr identical. The wires of each group are submerged and withdrawn in like manner. In passing from group to group, however, a change of acid is unavoidable.

TABLE 11.—*Solution of soft (S) steel, normal experiment.*

[Time, 1^h. $l=5^{cm}$. $\delta=7{\cdot}7$].

θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ
$M\times10^1$	$M\times10^2$	$M\times10^2$	$M\times10^2$	$M\times10^1$	$M\times10^1$	$M\times10^2$	$M\times10^1$	$M\times10^1$	$M\times10^1$	$M\times10^1$	$M\times10^2$
$r\times10^2$	$r\times10^2$	$r\times10^2$	$r\times10^1$	$r\times10^1$	$r\times10^2$	$r\times10^1$	$r\times10^1$	$r\times10^1$	$r\times10^1$	$r\times10^1$	$r\times10^2$
$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$	$\Delta r\times10^3$
32·4	32·4	32·4	31·6	31·6	31·6	33·3	33·3	33·3	31·5	31·5	31·5
495	496	497	351	354	355	207	209	211	90	93	93
63·8	64·0	64·0	53·8	54·0	54·2	41·3	41·5	41·7	27·2	27·7	27·7
0	0	0	2·8	2·7	2·6	3·5	3·4	3·3	3·0	2·9	3·1
32·3	32·3	33·3	32·5	32·5	32·5	33·3	33·3	33·3	31·7	31·7	31·7
464	466	467	314	316	317	171	174	175	65	68	68
61·9	62·0	62·1	50·8	51·0	51·1	37·6	38·0	38·1	23·1	23·6	23
1·9	2·0	1·9	3·0	3·0	3·1	3·7	3·5	3·6	4·1	4·1	4·1
32·3	32·3	32·3	32·5	32·5	32·5	32·8	32·8	32·8	32·0	32·0	32·0
426	427	428	280	281	282	137	140	142	41	43	44
59·3	59·4	59·4	48·0	48·1	48·2	33·7	34·1	34·3	18·3	18·8	19·0
2·6	2·6	2·7	2·8	2·9	2·9	3·9	3·9	3·8	4·8	4·8	4·6
32·0	32·0	32·0	33·0	33·0	33·0	31·5	31·5	31·5	32·0	32·0	32·0
389	390	391	243	244	245	111	114	115	21	23	23
56·6	56·7	56·8	44·8	44·9	45·0	30·2	30·6	30·8	13·1	13·7	13·7
2·7	2·7	2·6	3·2	3·2	3·2	3·5	3·5	3·5	5·2	5·1	5·3

Digitized by Google

TABLE 12.—*Solution of drawn steel, originally S.*

[$l = 4{\cdot}5^{cm}$. $\delta = 7{\cdot}7$.]

$M' \times 10^3$ $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	$M' \times 10^3$ $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^4$	$M' \times 10^3$ $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^4$	$M' \times 10^3$ $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	$M' \times 10^3$ $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	$M' \times 10^3$ $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	$M' \times 10^3$ $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
441	413	359	309	248	203	193
63·5	61·5	57·3	53·2	47·5	43·3	42·0
.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....
411	376	324	267	218	176	167
61·4	58·6	54·3	49·5	44·7	40·3	39·2
2·1	2·9	3·0	3·7	2·8	3·0	2·8
2·1	2·2	2·3	2·3	2.5	2·7	2·7
384	348	303	233	184	148	137
59·3	56·4	51·4	46·2	41·1	36·7	35·5
2·1	2·2	2·9	3·3	3·6	3·6	3·7
2·1	2·1	2·2	2·4	2·5	2·7	2·7
367	325	264	204	155	117	106
58·0	54·5	49·1	43·4	37·7	32·7	31·1
1·3	1·9	2·3	2·8	3·4	4·0	4·4
1·3	1·3	1·4	1·5	1·6	1·7	1·8
337	292	229	166	119	79	66
55·4	51·7	45·8	39·1	33·0	26·9	24·6
2·6	2·8	3·3	4·3	4·7	5·8	6·5
2·6	2·7	2·9	3·2	3·5	3·7	4·0
313	264	198	136	94	53	37
53·4	49·1	42·6	35·4	28·9	22·1	18·5
2·0	2·6	3·2	3·7	4·1	3·9	6·1
2·0	2·1	2·3	2·5	2·8	3·1	3·3
286	237	170	109	63	24	13
51·2	46·6	39·5	31·7	23·9	15·0	10·9
2·2	2·5	3·1	3·7	5·0	7·1	7·6
2·2	2·3	2·5	2·8	3·3	3·8	(4·3)
238	185	113	69	31		
46·7	41·2	32·1	25·2	16·7		
4·5	5·4	7·4	6·5	7·2		
4·5	4·8	5·9	6·0	7·2		
197	144	90	41	6		
42·5	36·5	28·7	19·5	7·5		
4·2	4·7	3·4	5·7	9.2		
4·2	4·6	5·3	6·3			
130	84	38	2			
34·5	27·8	18·6	4·7			
8·0	8·7	10·9	2·8			
8·0	8·9	10·3				
98	56	12				
30·0	22·7	10·5				
4·5	5·1	8·1				
4·5	5·1	6·5				
67	25					
24·8	15·4					
5·2	7·3					
5·2	6·8					

Digitized by Google

Tables 13, 14, 15 and 16 are constructed on the same plan as Tables 11 and 12. The steel wires, however, are of different temper. Table 3 contains the normal experiments, the rods being submerged in hydrochloric acid of a given strength throughout during successive intervals of two hours each. The rods are about 5^{cm} long, and Nos. 1, 2, 3 are annealed at red heat in air from the soft state; Nos. 4, 5, 6, annealed at red heat in air from the glass-hard state; No. 7 is glass-hard. θ, M, r, etc., have the signification already given. In Table 14 five soft rods, annealed at red heat in air, are tested. M', r', $\Delta r'$ are their solution data. Δr is interpolated from Table 13 by making the first term of Δr and $\Delta r'$ identical. In Table 15 six glass-hard rods, annealed at red heat in air, are tested. Notation as before. Abbreviations which refer to temper and hardness are given in § 19 above.

TABLE 13.—*Solution of soft (S A) steel, normal experiment.*

[$l = 5^{cm}$. $\delta = 7{\cdot}7$.]

S-S A.			G H-S A.			G H.
θ M $r\times10^1$ $\Delta r\times10^3$.	θ M $r\times10^2$ $\Delta r\times10^3$.	θ M $r\times10^3$ $\Delta r\times10^3$.	θ M $r\times10^1$ $\Delta r\times10^3$.	θ M $r\times10^2$ $\Delta r\times10^3$.	θ M $r\times10^3$ $\Delta r\times10^3$.	θ M $r\times10^1$ $\Delta r\times10^1$.
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
·489	·487	·486	·492	·495	·491	·489
63·5	63·4	63·2	63·7	63·8	63·5	63·5
32·4	32·4	32·4	32·4	32·4	32·4	32·4
·455	·452	·452	·461	·462	·461	·467
61·2	61·1	61·1	61·7	61·7	61·7	62·1
2·3	2·3	2·1	2·0	2·1	1·8	1·4
32·4	32·4	32·4	32·4	32·4	32·4	32·4
·415	·412	·413	·425	·425	·426	·441
58·5	58·3	58·3	59·3	59·3	59·3	60·3
2·7	2·8	2·8	2·4	2·4	2·4	1·8
28·7	28·7	28·7	28·7	28·7	28·7	28·7
·387	·383	·385	·398	·396	·400	·423
56·5	56·2	56·3	57·2	57·2	57·5	59·1
2·0	2·1	2·0	2·1	2·1	1·8	1·2
29·4	29·4	29·4	29·4	29·4	29·4	29·4
·358	·354	·356	·372	·369	·374	·404
54·3	54·0	54·1	55·4	55·1	55·5	57·6
2·2	2·2	2·2	1·8	2·1	2·0	1·5
29·3	29·3	29·3	29·3	29·3	29·3	29·3
·328	·325	·327	·345	·341	·348	·384
52·0	51·8	52·0	53·4	53·0	53·6	56·2
2·3	2·2	2·1	2·0	2·1	1·9	1·4
	29·5	29·5	29·5	29·5	29·5	29·5
	·296	·299	·318	·313	·320	·363
	49·5	50·3	51·3	50·8	51·4	54.8
	2·3	1·7	2·1	2·2	2·2	1·4

Digitized by Google

TABLE 13.—*Solution of soft (S A) steel, normal experiment*—Continued.

[l=5^{cm}. δ=7·7.]

S–S A.			G H–S A.			G H.
$\frac{\theta}{M}$ $r\times10^3$ $\Delta r\times10^3$.	$\frac{\theta}{M}$ $r\times10^3$ $\Delta r\times10^3$	$\frac{\theta}{M}$ $r\times10^3$ $\Delta r\times10^3$.	$\frac{\theta}{M}$ $r\times10^3$ $\Delta r\times10^3$.	$\frac{\theta}{M}$ $r\times10^3$ $\Delta r\times10^3$.	$\frac{\theta}{M}$ $r\times10^3$ $\Delta r\times10^3$.	$\frac{\theta}{M}$ $r\times10^3$ $\Delta r\times10^3$.
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
	29·5	29·5	29·5	29·5	29·5	29·5
	·271	·276	·293	·287	·297	·345
	47·3	47·7	49·2	48·7	49·6	53·3
	2·2	2·6	2·1	2·1	1·8	1·5
	30·0	30·0	30·0	30·0	30·0	30·0
	·241	·245	·269	·261	·273	·326
	44·7	45·0	47·0	46·4	47.5	51·9
	2·6	2·7	2·2	2·3	2·1	1·4
	30·0	30·0	30·0	30·0	30·0	30·0
	·213	·218	·241	·233	·247	·306
	41·8	42·4	44·5	43·7	45·1	50·2
	2·9	2·6	2·5	2·7	2·4	1·7
	30·0	30·0	30·0	30·0	30·0	30·0
	·188	·193	·218	·208	·223	·287
	39·4	39·9	42·4	41·4	42·9	48·6
	2·4	2·5	2·1	2·3	2·2	1·6
	30·0	30·0	30·0	30·0	30·0	30·0
	·170	·174	·200	·189	·205	·271
	37·5	37·9	40·7	39·5	41·2	47·3
	1·9	2·0	1·7	1·9	1·7	1·3
	31·5	31·5	31·5	31·5	31·5	31·5
	·146	·152	·177	·164	·183	·250
	34·7	35·5	38·2	36·7	38·9	45·4
	2·8	2·4	2·5	2·8	2·3	1·9
	29·0	29·0	29·0	29·0	29·0	29·0
	·124	·129	·156	·144	·162	·232
	31·9	33·1	35·9	34·4	36·6	43·8
	2·8	2·4	2·3	2·3	2·3	1·6
	28·3	28·3	28·3	28·3	28·3	28·3
	·107	·112	·138	·124	·144	·217
	29·6	30·5	33·7	32·0	34·6	42·3
	2·3	2·6	2·2	2·4	2·0	1·5
	27·6	27·6	27·6	27·6	27·6	27·6
	.089	·094	·120	·106	·127	·202
	27·0	27·8	31·5	29·5	32·3	40·8
	2·6	2·7	2·2	2·5	2·3	1·5
	27·0	27·0	27·0	27·0	27·0	27·0
	·073	·078	·101	·089	·110	·187
	24·5	25·4	29·2	27·1	30·1	39·2
	2·5	2·4	2·3	2·4	2·2	1·6

Digitized by Google

TABLE 14.—*Solution of drawn steel, originally S, changed to SA.*

[l=4.0^{cm}. δ=7.7.]

M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
·390	·340	·264	·212	·167
68·4	59·1	52·1	46·8	41·5
·381	·329	·251	·201	·153
62·7	58·2	50·8	45·6	39·8
0·7	0·9	1.3	1·2	1·7
0·7	0·7	0·7	0·8	0·8
·372	·321	·242	·188	·143
61·9	57·5	50·0	44·3	38·5
0·8	0·7	0·8	1·3	1·3
0·8	0·8	0·8	0·9	0·9
·368	·316	·235	·180	·134
61·3	57·0	49·2	43·1	37·1
0·5	0·5	0·8	1·2	1·4
0·5	0·5	0·5	0·6	0·6
·359	·307	·225	·169	·121
60.8	56·3	48·2	41·8	35·3
0·5	0·7	1.0	1·3	1·8
0·5	0·5	0·5	0·6	0·6
.352	·301	·215	·159	·107
60·3	55·7	47.2	40·7	33·4
0·5	0·6	1·0	1.1	1·9
0·5	0·5	0.5	0·6	0·6
·346	·293	·205	·148	·094
59·8	54·9	46·0	39·1	31·2
0·5	0·8	1·2	1·6	2·2
0·5	0·5	0.6	0·6	0·6
·330	·271	·183	·124	·068
58·4	52·8	43·3	35·8	26·6
1·4	2·1	2·7	3·3	4·6
1·4	1·4	1·5	1·6	1·7
·312	·259	·162	·102	·047
56·9	51·6	41·3	32·8	22·3
1·5	1·2	2·0	3·0	4·3
1·5	1·6	1·6	1·7	1·8
·277	·223	·129	·066	·014
53·4	47.9	36.5	26·1	11.8
3·5	3·7	4.8	6.7	10·5
3·5	3·6	3·8	4·1	
·264	·206	·110	·048	
52·0	46·2	33·7	22·5	
1·4	1·7	2·8	3·6	
1·4	1·4	1·6	1·7	

Digitized by Google

TABLE 14.—*Solution of drawn steel, originally S, changed to SA*—Continued.

[l=4.0^{cm}. d=7.7.]

M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$	M' $r'\times10^3$ $\Delta r'\times10^3$ $\Delta r\times10^3$
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
·246	·188	·093	·031	
50·4	44.1	31·1	18·0	
1·6	2.1	2·6	4·5	
1·6	1·7	1·8	1·9	
·230	·171	·075	·016	
48·7	42·2	27·9	13·3	
1·7	1·9	3.2	4·7	
1·7	1·8	1·9		
·214	·156	·058		
46·9	40·2	25·0		
1·8	2·0	2·9		
1·8	1·9	2.1		
·199	·140	·043		
45·3	38·1	21·4		
1·6	2·1	3.6		
1·6	1·6	1·8		
·176	·117	.026		
42·6	34·6	16·5		
2·7	3·5	4·9		
2·7	2·8			
·143	·086			
38·5	29·8			
4·1	4·8			
4·1	4.3			
·129	·072			
36·5	27·3			
2·0	2·5			
2·0	2·1			

Digitized by Google

TABLE 15.—*Solution of drawn steel, originally GH, changed to SA.*

[l=3·8^{cm} to 4·0^{cm}. δ=7·7.]

M' $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	M' $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	M' $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	M' $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	M' $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$	M' $r' \times 10^3$ $\Delta r' \times 10^3$ $\Delta r \times 10^3$
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
·393	·321	·272	·229	·186	.....
63·8	59·0	54·3	49·9	44·9	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
·382	·311	·261	·217	·176	·151
62·8	58·7	53·2	48·5	43·7	40·5
1·0	1·3	1·1	1·4	1·2	.....
1·0	1·0	1·1	1·1	1·2	.....
·375	·305	·254	·209	·168	·143
62·1	57·4	52·4	47·8	42·9	39·8
0·7	1·3	0·8	0·7	0·8	0·7
0·7	0·7	0·7	0·7	0·8	0·8
·371	·303	·249	·204	·164	·139
61·8	57·3	52·0	47·2	42·3	39·4
0·3	0·1	0·4	0·6	0·6	0·3
0·3	0·3	0·3	0·3	0·3	0·3
·363	·294	·242	·195	·154	·137
61·1	56·5	51·2	46·0	40·9	38·6
0·7	0·8	0·8	1·2	1·4	0·8
0·7	0·7	0·7	0·7	0·8	0·8
·356	·288	·235	·187	·148	·126
60·5	55·9	50·5	45·1	40·1	37·0
0·6	0·6	0·7	0·9	0·8	1·6
0·6	0·6	0·6	0·7	0·7	0·7
·350	·282	·229	·180	·139	·119
60·1	55·2	49·9	44·2	38·8	36·0
0·4	0·7	0·6	0·9	1·3	1·0
0·4	0·4	0·4	0·5	0·5	0·5
·329	·260	·207	·156	·116	·094
58·3	53·1	47·5	41·1	35·3	32·1
1·8	2·1	2·4	3·1	3·5	3·9
1.8	1·8	1·9	2·0	2·0	2·0
·311	·244	·188	·136	·096	·072
56·7	51·4	45·3	38·4	32·2	28·0
1·6	1·7	2·2	2·7	3·1	4·1
1·6	1·7	1·8	1·8	1·9	2·7
·277	·214	·156	·102	·055	·027
53·4	48·3	41·2	33·3	25·4	18·3
3·3	3·1	4·1	5·1	6·8	9·7
3·3	3·4	3·6	3·7	4·0	4·0
·261	·199	·138	·081	·038	·014
51·9	46·5	38·7	29·6	21·3	12·7
1·5	1·8	2·5	3·7	4·1	5·6
1·5	1·5	1·6	1·7	1·8	

Digitized by Google

TABLE 15.—*Solution of drawn steel, originally GH, changed to SA.*—Continued.

[l=3·8^{cm} to 4·0^{cm}. δ=7·7.)

M' $r'\times10^2$ $\Delta r'\times10^1$ $\Delta r\times10^1$	M' $r'\times10^2$ $\Delta r'\times10^1$ $\Delta r\times10^1$	M' $r'\times10^2$ $\Delta r'\times10^2$ $\Delta r\times10^2$	M' $r'\times10^2$ $\Delta r'\times10^2$ $\Delta r\times10^2$	M' $r'\times10^2$ $\Delta r'\times10^2$ $\Delta r\times10^2$	M' $r'\times10^2$ $\Delta r'\times10^2$ $\Delta r\times10^2$
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
·244	·183	·121	·065	·021	
50·1	44·6	36·5	27·4	16·7	
1·8	1·9	2·2	2·2	4·6	
1·8	1·9	2·0	2·1		
·229	·167	·105	·049	·008	
48·6	42·5	33·7	23·3	11·8	
1·5	2·1	2·8	4·1	4·9	
1·5	1·6	1·7	1 8		
·213	·150	·090	·034		
46·9	40·3	31·4	19·4		
1·7	2·2	2·3	3·9		
1·7	1·8	1·9	2·0		
·197	·136	·074	·021		
45·1	38·5	28·5	15·4		
1·8	1·8	2·9	4·0		
1·8	1·8	2·0			
·174	·114	·053			
42·4	35·2	24·0			
2·7	3·3	4·5			
2·7	2·8	3·0			
·140	·085	·028			
38·1	30·3	18.8			
4·3	4·9	5·2			
4·3	4·5				

Digitized by Google

Finally, in table 16, solution comparisons are made between glass-hard and soft wires, in the way indicated for the preceding tables. Rods Nos. 1 and 2 are glass-hard; Nos. 3 and 4 soft; Nos. 5 and 6 annealed at low red heat in air; No. 7 annealed at very high red heat in air. The time of submergence was 3 hours.

TABLE 16.—*Solution of steel, GH, S, SA.*

[l=5^{cm}. Δ=7·7.]

GH.		S.		S–SA.		SA.	
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	θ
$M\times10^3$ $r\times10^3$ $\Delta r\times10^3$	$M\times10^3$ $r\times10^3$ $\Delta r\times10^3$	$M\times10^3$ $r\times10^3$ $\Delta r\times10^3$	$M\times10^3$ $r\times10^3$ $\Delta r\times10^3$	$M\times10^3$ $r\times10^3$ $\Delta r\times10^3$	$M\times10^3$ $r\times10^3$ $\Delta r\times10^3$	$M\times10^3$ $r\times10^3$ $\Delta r\times10^3$	
487	201	489	205	487	199	487	
63·4	40·7	63·5	41·1	63·4	40·5	63·4	
483	199	445	189	477	195	481	28
63·1	40·5	61·2	39·8	62·7	40·1	63·0	
0·3	0·2	2·3	1·3	0·7	0·4	0·4	
477	196	387	167	465	191	475	28
62·7	40·2	57·7	37·8	62·1	39·8	62·5	
0·4	0·3	3·5	2·0	0·6	0·3	0·5	
469	193	324	144	453	186	469	
62·2	39·9	53·3	35·4	61·4	39·3	62·2	
0·5	0·3	4·4	2·4	0·7	0·5	0·3	
462	189	259	120	439	181	462	
61·7	39·4	48·2	32·6	60·4	38·7	61·7	
0·5	0·5	5·1	2·8	1·0	0·6	0·5	
455	186	201	99	424	176	455	
61·2	39·2	42·8	29·8	59·4	38·3	61·2	
0·5	0·2	5·4	2·8	1·0	0·4	0·5	
448	183	146	78	412	170	447	
60·8	38·8	36·9	26·8	58·6	37·7	60·7	
0·4	0·4	5·9	3·0	0·8	0·6	0·5	
442	180	102	61	400	165	442	
60·4	38·5	31·0	23·8	57·8	37·1	60·4	
0·4	0·3	5·9	3·0	0·8	0·6	0·3	
436	177	.....	45	387	161	435	
60·0	38·2	.....	20·5	57·0	36·7	59·8	
0·4	0·3	.....	3·3	0·8	0·4	0·6	

DISCUSSION.

32. *Incidental errors.*—I may state at the outset that secondary errors, such, for instance, as might be ascribed to passivity of steel, are largely avoided. Care was taken to rub the rod with platinum at the beginning of each solution. Nevertheless, it is not impossible, when the rods were left to dry over night, at the close of a day's series of experiments, that some retardation during the first stages of solution on

Digitized by Google

the succeeding day may be appreciable. A serious difficulty is encountered because of the unavoidable change of the room temperature during the successive solutions. In some instances I endeavored partially to avoid this by making the solution in the cellar underneath the laboratory. But even here the temperature is insufficiently constant for fine work.

33. *Effect of surface.*—As regards the plan of treating the above results, it appears probable that the masses dissolved in case of a given sample and given solvent, must be simply a function of radius and time (correction being made, of course, for loss at the ends). If the rate of solution be denoted by ρ, its value at the radius r must be

$$\rho_r = -\delta \cdot 2\pi r dr / 2\pi r dt$$

where δ is the density of the sample and dt the elementary time of solution. ρ therefore is the mass dissolved under the given condition of form and solvents per unit of surface, per unit of time. Thus it appears that the mean rate during the time t will be

$$(\int \rho_r dt)/t \text{ or } -(\delta/t)/\int dr,$$

each taken between corresponding limits. In other words the mean rate

$$\rho = \frac{1}{t}\int_{t_1}^{t_2} \rho_r dt = \frac{\delta}{t}(r_2 - r_1)$$

where $t_2 - t_1 = t$. If therefore t be chosen constant, rates of solution are to each other as

$$\frac{\rho'}{\rho} = \frac{r_2' - r_1'}{r_2 - r_1}.$$

It is, therefore, an apparently simple problem to deduce the relative mean rate directly from the differences of radii—time, figure, and chemical conditions remaining the same. But from the data of the above tables such simple relations do not at all appear. Indeed the corresponding differences of mass dissolved are very much more nearly constant than the corresponding differences of radii. In other words, in the case of cylindrical figures of small radius, the mass dissolved is nearly independent of radius; i. e., independent of the surface exposed to the action of acid. The conditions are such that fixed masses of solid are transferred by solution to the liquid state, and in proportion as radius diminishes the thickness of shell dissolved in given times rapidly increases.

34. *Effect of diffusion.*—Without doubt the underlying cause of this observation is a diffusion phenomenon. For instance, let c be the concentration at the surface of separation of solid and liquid, the radius being r. Then $c.2\pi r dr$ is the amount of salt dissolved in the first liquid shell. Now, when this salt dissolved is transferred by diffusion to a distance r' ($r' > r$), the concentration c' is necessarily smaller, for $c.2\pi r dr = c'2\pi r' dr'$, or $cr = c'r'$. It follows at once that the difference of concentration for a given value of dr increases at a rapid rate when the radius approaches zero. On the other hand the rate of transference

Digitized by Google

of the solid material into the liquid state must depend on the rapidity with which c diminishes in the direction of r. Hence the rate of solution will increase in proportion as smaller thicknesses of wire are encountered, inasmuch as the conditions favorable for the transportation of the dissolved metal are enhanced. This follows more rigorously from Fick's law. Adapting Fourier's theory of heat conduction to questions involving diffusion, Fick[1] proposed $dc/dt = \varkappa d^2c/dx^2$, where c is the concentration and $\varkappa$ the diffusion constant. In other words, the time rate at which concentration progresses is proportional to the space rate of increase of the same quality. The truth of this fundamental assumption was afterwards rigorously tested by H. F. Weber.[2] Fick's equation, when $dc/dt = 0$, or the diffusion has become stationary, referred to polar coordinates is $d^2(rc)/dr^2 = 0$. Since $c = 0$ for $r = \infty$, this reduces to $cr = c'r'$.

The diffusion effect will necessarily be of smaller consequence when solution takes place at very low rates; for instance, in the case of glass-hard steel. It is also greatly modified, past recognition, perhaps, by the escape of gases from the body undergoing solution. In this way convective currents are set up accompanied by distributive effects very much more rapid than the diffusion phenomenon. A further disturbance is gravitational convection.

35. *Wires originally soft.*—Nevertheless, in discussing the above results, it is advisable to consider the relative consecutive value of ΔM for given comparable conditions of solution, quite as much as the relative values of Δr, or the consecutive rates. Inasmuch as there is a striking tendency toward constant values of ΔM independent of r, when r lies below a critical value, apparent in all my results, it is probable that a law characteristic of the solution of filimentary or small bodies is here expressed.

Turning first to Table 11, the following correlative values of $r = (r_2 + r_1)\frac{1}{2}$; $\rho = r_2 - r_1$ and $\Delta M = M_2 - M_1$ are apparent. The variable ρ is identical with the rate, since the times and chemical conditions of solution are constant.

TABLE 17.—*Digest for originally soft wires.*

$r \times 10^3 =$.....	63	61	58	55	52	49	46	43	40	36	32	29	25	21	16
$\rho \times 10^3 =$.....	2·0	2·6	2·7	2·7	3·0	2·9	3·2	3·4	3·6	3·9	3·5	3·0	4·1	4·7	5·2
$\Delta M \times 10^3 =$.....	30	39	37	37	37	35	37	35	36	33	27	21	25	24	21

The salient property of these data is the rapid increase of rate encountered immediately after the superficial layer is dissolved off. After this ΔM is nearly constant between $r = .060^{cm}$ and $r = .040^{cm}$, whereupon it decreases rapidly. On the other hand ρ increases continually and at an accelerated rate. Irregularities of outline are doubtless

[1] Fick: Pogg. Ann., xciv, p. 59, 1855; Phil. Mag. (4), x, p. 30, 1855.
[2] H. F. Weber: Phil. Mag. (5), viii, p. 523, 1879; Wied. Ann., vii, p. 469, 536, 1879.

Digitized by Google

the effect of temperature. The distortion is greatest in the curve for ΔM. With these data the seven drawn rods of Table 12 are to be compared. As before $2r' = r'_1 + r'_2$ and $\rho' = r'_2 - r'_1$ for each solution, and Table 11 furnishes values of ρ in case of the normal rod, for every value of r'. By making the first term of each series identical a corresponding series of $\Delta r = \rho$ is obtained. It is expedient to represent ρ and ρ' graphically as functions of r'. If this be done it appears that after the first shell is dissolved, the solution of drawn wire takes place at greater rates than the solution of homogeneous wire of the same radius. After dissolving seven shells the results show irregularities, easily accounted for inasmuch as the finer rods gradually become of irregular shape and fissured. Again the results for ΔM may be represented as a function of r', showing values, which as a rule, increase as r' decreases. From these data as a whole it follows that drawn steel is cæt. par. more easily soluble than homogeneous steel; again after the superficial layers are removed the rate of solution increases with the intensity of drawn strain or resilient properties of the wire.

36. *Wires annealed.*—Turning now to the results of Table 3, in which the normal data for wires softened in air and for a glass-hard wire are inserted, it is clear in the first place that as soon as the superficial layers are removed the rate of solution increases. This result corroborates Table 11. Apart from this, however, the variations of rate of solution and of the other data are here of a much smaller order than was the case for Table 11. ΔM decreases with radius at a somewhat more rapid rate than before, and hence $\rho' = \Delta r'$ now increases at a decidedly less rapid rate than in Table 11. This is shown in the following summary for wires softened in air (i. e., S–SA and GH–SA).

TABLE 18.—*Digest for wires annealed in air.*

$10^3 \times r =$	62	60	58	56	54	52	50	46	44	42	40	38	35	33	30	26
$10^3 \times \rho' =$	2·1	2·6	2·0	2·1	2·1	2·1	2·2	2·4	2·6	2·3	1·8	2·5	2·4	2·3	2·4	2·4
$10^3 \times \Delta M =$ ..	33	38	27	27	28	29	19	27	28	24	18	23	22	17	17	17

It is also shown in the results for the glass-hard wire (G. H.), identically submerged.

TABLE 19.—*Digest for hard wires.*

$10^3 \times r =$	63	61	60	58	57	55	54	53	51	49	48	46	45	43	41	40
$10^3 \times \rho =$	1·4	1·8	1·2	1·5	1·4	1·4	1·5	1·4	1·7	1·6	1·3	1·9	1·6	1·5	1·5	1·6
$10^3 \Delta M =$	22	26	18	19	20	21	18	19	20	19	16	21	18	14	16	15

With these data the values of tables 14 and 15 are to be compared in a way already enunciated in case of tables 11 and 12. The data being constructed graphically, it again follows, almost without exception, that both in tables 14 and 15 the rates of solution of drawn wires are greater than the similarly circumstanced rates for homogeneous wires.

Digitized by Google

There also is a weight of evidence in favor of the result that solution increases with the degree of resilience, i. e., the intensity of the drawn strain. In other words, rate of solution increases as the (drawn) diameter of the wire of each group diminishes, supposing as above that the superficial layers of the wire have been removed. Finally, in Table 14, ΔM also continually increases from larger to smaller diameters, for each group, until the diameter of the rod has been considerably reduced. In Table 15, however, this result is not so pronounced, and ΔM remains nearly constant.

Summarizing the above results as a whole, it follows that the rate of solution of drawn steel is greater than the rate of the same homogeneous metal similarly circumstanced. After the superficial layers (probably dense low-carbon steel) have been removed, the rate of solution increases with the intensity of drawn strain. To a smaller and less definite extent this is true also of the masses dissolved in equal times, in cases of resilience of different intensities, other things remaining the same.

37. *Relation to Drowne's inferences.*—Table 16 finally has been drawn up to show the enormous difference of rate of solution between glass-hard and soft steels. Submergence being identical for all rods, it is curious in the first place to note the difference of rate of Nos. 3 and 4, both being very soft steel, as well as the high rates of solution of these two rods as compared with the others. The special feature of these experiments is the fact that rods annealed at red heat in air dissolve quite as slowly as rods quenched glass hard; and this is particularly the case when the rods are annealed at high-red heat, No. 7. This observation calls to mind the inference of Dr. Drowne[1], viz, that "there is a limited range of temperature probably near the point of solidification of the metal, within which the separation of carbon from iron takes place, and that the amount of carbon separated in any given instance is proportional to the time consumed by the pig iron in passing through the limited range of temperature." Now, as the rate of solution increases directly with the free carbon in steel, caet. par., the present data substantiate Dr. Drowne's reasoning.

38. *Summary.*—Perusing the above pages as a whole, they furnish evidence favoring the opinion that the effect of strain on metallic structure is a reconstruction of the metallic molecule; but since the rate of solution of the drawn metal is greater, it does not follow that the results so obtained are due to the presence of β iron in α iron, unless it be supposed that the negative character of the former relative to the positive quality of α iron increases the rate of solution by local electric action. The corrugated and deeply fissured appearance of the rods after the radius has been much reduced is in keeping with this view. Indeed, an exceedingly curious action, which I frequently observed, may be mentioned. It often happens that the solution at the

[1] T. M. Drowne: Trans. Am. Inst. Mining Eng., III, 1874–'75, p. 41.

Digitized by Google

ends of the rod, instead of rounding off the corners, eats its way decidedly into the axis, so as to form a reentrant cone of some depth. Again, if there be periodic distributions of density from the surface inward, an inference which from earlier observations[1] with glass-hard rods does not seem improbable, the regularity of solution experiments would be disturbed.

[1] Cf. Bull. U. S. Geol. Survey, No. 35, p. 38, 1886.

Digitized by Google

CHAPTER V.

THE HYDROELECTRIC EFFECT OF CHANGES OF MOLECULAR CONFIGURATION.

INTRODUCTORY.

39. The hydroelectric method is usually regarded as the most delicate criterion for testing changes of molecular constitution in metals. Unfortunately its indications are, in the present instance, distorted by polarization. Polarization, moreover, is apt to be much larger than the effect to be studied, so that the observer is obliged to resort to methods of measurement in which a fair degree of constancy of the error in question may be assured. From this it follows that unless the hydroelectric forces are as large as the interval "glass hard" to "soft," the effect of strains which can not be applied without removing the wire or metal from the hydroelectric bath is not observable. For in such a case the polarization varies with each immersion. Moreover, certain strains, like the drawn strain, show different mechanical conditions at different distances from the axis. Hence the hydroelectric constant of such a rod, were it obtainable, would be a complex magnitude.

In magnetization, the hydroelectric effect of which has been discovered by Remsen[1] and studied by Nichols[2], and more recently by Rowland and Bell[3], small hydroelectric effects ($<.03$ volts) can be detected because the metal during straining remains in place. Among other mechanical strains, traction, and perhaps torsion, admits of similar application to a metallic wire in place.

APPARATUS.

40. In the annexed figure 4 I have shown the apparatus used. *aac* and *bb* are consecutive pieces of a given kind of soft wire. Of these *aa* is to be stretched, *bb* examined in the homogeneous state. Hence *aa* is fixed between two points, of which the lower is on the circumference of an iron drum, *D*, which can be rotated by aid of the lever *LL* and frictionally fixed in position after any rotation. Usually the arcs of rotation of *D* were 180°, and four or five such strains could be applied to the wire consecutively before rupture ensued.

---

[1] Remsen: Am. Chemical Journal, III, p. 157, 1881.
[2] Nichols: Am. Jour. Sci., XXXI, p. 272, 1886: ibid., XXXV, p. 290, 1887.
[3] Rowland and Bell: Phil. Mag. (5), XXVI, p. 105, 1888.

Digitized by Google

Before and after each of these strains measurements of hydroelectric state were made. For this purpose both wires are surrounded by glass tubes *AA* and *BB* respectively, held together by aid of the little block of wood *C*. These tubes were closed below with rubber corks through which the wires passed without leakage. The tubes were filled either with a concentrated solution of zinc sulphate, or with distilled water, or other material which does not act strongly on the metal. The electrolytic connection between *AA* and *BB* is made by a siphon, *S*, filled with the liquid of the tubes and closed at *s* with a parchment septum. The upper ends of the wires *b* and *c* were in connection with the terminals of a Mascart electrometer, or with the properly adjusted wires of an apparatus for a zero method.

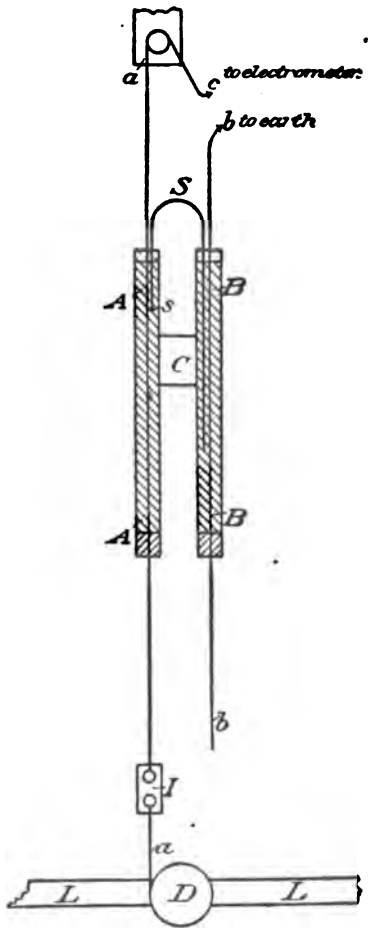


FIG. 4. Apparatus for measuring the hydroelective effect of stretching.

After straining the wire *aac* to the point of breakage, the apparatus was reversed and *bb* now strained in the same manner. In this way the number of distinct measurements for each adjustment could be doubled.

The wire being 54^{cm} long and the diameter of the drum about 1.7^{cm} the extension of wire per rotation of 180° was approximately 2.6^{cm}, or $\delta L/L=.05$ nearly. The amount differed slightly when wires of different thicknesses were used. The reduction of diameter of iron wire before and after straining to breakage is therefore considerable.

EXPERIMENTS.

41. *Zero method.*—In communicating my results I will omit the data obtained galvanically by the zero method. For the polarization disturbances are here of larger order than in electrometric work, an annoyance which vitiates the greater delicacy of measurement. The remark, however, is not superfluous that all the results were found to corroborate the electrometric data.

42. *Results for iron.*—The hydroelectric effect of traction is characterized by a temporary and a more or less permanent part. The temporary part may be given by observing the differences of potential at the end of each minute after straining, as well as the throw of the needle

Digitized by Google

immediately after. The difference of potential which remained when the temporary effect had subsided I called the permanent part. An allowance of five minutes was usually regarded sufficient. Of course this assumption is arbitrary; but whatever errors are committed are of like effect throughout the series. The value of the throw is expressed in volts, as are the other data. In all I made about 7 series of this kind, two of which are given in Table 20. The diameter of the iron wires before straining was $2\rho_s = \cdot 086^{cm}$; after breaking $2\rho_h = \cdot 078^{cm}$.

TABLE 20.—*Hydroelectric effect of tensile strain.*

IRON WIRE.

Strain.	$e \times 10^3$ temporary.					$e \times 10^3$ permanent.	Strain.	$e \times 10^7$ temporary.					$e \times 10^3$ permanent.
	Throw.	1st	2nd	3rd	4th			Throw.	1st	2nd	3rd	4th	
0						+ 9	0						+ 0
I	−34					+ 7	I	−18					+ 5
II	− 0					+11	II	− 2					+ 9
III	+ 8					+14	III	+ 5					+11
IV						+ 0	IV	+10					+13
0						−14	0						− 6
I	−26					−13	I	−15					− 1
II	− 0					− 8	II	− 0					− 0
III	+10					− 4	III	+ 2					+ 2
IV	+12					− 1	IV	+ 5					+ 3

Extension, $\delta L / L = \cdot 05$ per pull.
Radial contraction, $\delta\rho / \rho < \cdot 03$ per pull.
Mean permanent potential increase $= + \cdot 003$ volts per pull.

The character of the data of table 20 is such as to indicate superimposed permanent and temporary effects. The former is distinctly electropositive in all my results; negative differences of potential are numerically decreased, positive differences increased. The increase of electropositive quality takes place simultaneously with the increase of length, at a rate which varies somewhat in the different experiments, but the mean value of which is about .003 volts per pull of the extension $\delta L/L = 0{\cdot}05$. This is equivalent to a decrease of the wetted external surface of the wire of about 5 per cent, provided there be no change of volume. The measured value is less than this, for the circumference before straining was found by aid of the micrometer to be $2\pi\rho_s = .27^{cm}$ and after straining $2\pi\rho_h = .24^{cm}$ as an aggregate of four pulls. This corresponds to less than 3 per cent of diminution of the wetted surface per pull.

The temporary effect is equally definite in character. Independently of the value of the permanent effect, the former is at first invariably negative, which quality is successively reduced, until finally the value, having passed through zero, becomes positive. The intensity of the first negative throw is strong; as a rule more so than the final positive throw.

Digitized by Google

DISCUSSION OF RESULTS.

43. Having thus obtained some knowledge of these phenomena for iron, it is expedient to indicate in passing some reasons for their probable cause. Iron submerged in any aqueous solution is polarized positively by a coat of hydrogen. Hence it is practically a condenser, whose capacity increases directly with the *wetted* surface, cæteris paribus. The effect of strain is therefore of a twofold kind: In consequence of the jarring and vibration which unavoidably accompany the stretching, some of the hydrogen is mechanically shaken off, and the positive potential or positive polarization decreased to a lower limit. Hence the *negative* throw after the first strain. Simultaneously with this result the capacity of the wire is diminished in consequence of stretching. Hence the positive potential or positive polarization is increased. If this last effect gradually predominates over the other (effect of jarring), the temporary throw changes from negative to positive.

This explanation is nearest at hand, and it need not be sufficient; but it is clear at once that before any hydroelectric effect can be ascribed to strain *as such*, it is necessary, to evaluate the polarization effect, as well as other minor errors, such for instance as are due to the increase of temperature of the wire during stretching. (Cf. Wiedemann's "Elektricität," vol. II, p. 773, etc.)

DATA FOR DIVERS METALS.

44. In the following tables I have inserted data corresponding to Table 20, but obtained with German silver, brass, copper, iron, all the wires being of larger diameter than before. The notation is the same as above. In Tables 21 to 24 zinc sulphate in concentrated solution is the electrolyte; in Tables 25 to 27 distilled water is used. At the ends of tables, the mean values per pull of extension ($\delta L/L$), radial contraction ($\delta\rho/\rho$), permanent potential increase e volts, are inserted for each wire.

TABLE 21.—*Hydroelectric effect of tensile strain.*

German silver, zinc sulphate, $\begin{cases} 2\rho_a = \cdot 102^{cm}. \\ 2\rho_b = \cdot 093^{cm}. \end{cases}$

Strain.	$e\times10^3$ temporary.					$e\times10^3$ permanent.
	Throw.	1m	2m	3m	4m	
0	.....	.....	.....	.....	.....	+27
I	+36	12	12	13	16	+28
II	+42	16	6	— 4	—19	+35
III	+50	19	—1	—10	—18	+47
IV	+69	42	18	9	2	+51
0	.....	.....	.....	.....	.....	+24
I	+32	13	7	4	4	+30
II	.....	.....	.....	.....	.....	+26
III	.....	.....	.....	.....	.....	+24
IV	.....	.....	.....	.....	.....	+23
V	.....	.....	.....	.....	.....	+18

$\delta L/L$ = Extension per pull = .05.
Radial contraction per pull = .02.
Mean permanent potential increase per pull = .005.

Digitized by Google

TABLE 22.—*Hydroelectric effect of tensile strain.*

Brass, zinc sulphate, $\begin{cases} 2\rho_a = \cdot166^{cm}. \\ 2\rho_b = \cdot157^{cm}. \end{cases}$

Strain.	$e\times10^3$ temporary.					$e\times10^3$ permanent.
	Throw.	1m	2m	3m	4m	
0	.....	.....	.....	.....	.....	+23
I	+21	18	12	12	13	+39
II	+41	31	28	25	24	+59
III	+48	30	20	18	15	+65
IV	.....	.....	.....	.....	.....	.....
0	.....	.....	.....	.....	.....	—15
I	+17	4	2	0	—2	—18
II	18	10	6	3	1	—18

$\delta L\ L$ = Extension per pull = ·05.
Radial contraction per pull = ·015.
Mean permanent potential increase per pull = ·015.

TABLE 23.—*Hydroelectric effect of tensile strain.*

Copper, zinc sulphate, $\begin{cases} 2\rho_a = \cdot166^{cm}. \\ 2\rho_b = \cdot150^{cm}. \end{cases}$

Strain.	$e\times10^3$ temporary.					$e\times10^3$ permanent.
	Throw.	1m	2m	3m	4m	
0	.....	.....	.....	.....	.....	+4
I	0	0	0	0	0	+6
II	0	0	0	0	0	+6
III	+3	2	1	2	2	+6
IV	+2	2	.....	.....	.....	.....
0	.....	.....	.....	.....	.....	—6
I, II	+2	2	2	2	.....	+0
III, IV	2	2	2	.....	.....	—1

Extension per pull = ·05.
Radial contraction per pull = ·025.
Mean permanent potential increase per pull = ·001.

TABLE 24.—*Hydroelectric effect of tensile strain.*

Iron, zinc sulphate, $\begin{cases} 2\rho_a = \cdot156^{cm}. \\ 2\rho_b = \cdot147^{cm}. \end{cases}$

Strain.	$e\times10^3$ temporary.					$e\times10^3$ permanent.
	Throw.	1m	2m	3m	4m	
0	.....	.....	.....	.....	.....	+8
I	—58	—42	—29	—22	—17	—6
II	—36	—24	—12	— 1	— 5	—5
III	—22	— 3	— 2	— 2	— 1	—3
IV	—36	—24	—17	—14	—10	—7
0	.....	.....	.....	.....	.....	+4
I	—52	—38	—24	—18	—15	—7
II	—30	—17	—10	— 6	— 4	—7
III	—30	—18	— 6	— 4	— 0	—7
IV	.....	.....	.....	.....	.....	.....

Extension per pull = ·05.
Radial contraction per pull = ·015.
Mean permanent potential increase per pull = ·033.

Digitized by Google

TABLE 25.—*Hydroelectric effect of stretching.*

Brass, water $\begin{cases} 2\rho_s = \cdot166\ \text{ohm}. \\ 2\rho_h = \cdot154\ \text{ohm}. \end{cases}$

Strain.	$e \times 10^3$, temporary.					$e \times 10^3$, permanent.
	Throw.	1m	2m	3m	4m	
0	.....	.....	.....	.....	.....	— 76
I	+82	73	59	48	39	— 44
II	+58	40	22	8	—2	— 52
III	+63	49	28	14	7	— 56
IV	+62	44	27	14	8	— 60
0	.....	.....	.....	.....	.....	+ 73
I	+42	42	42	38	36	+103
II	+21	14	13	8	6	+ 91
III	+28	21	11	—1	0	+ 77
IV	+29	24	14	7	3	+ 67

Extension per pull = ·05
Radial contraction per pull = ·02
Mean permanent potential increase per pull = ± ·015

TABLE 26.—*Hydroelectric effect of stretching.*

Iron, water $\begin{cases} 2\rho_s = \cdot135\ \text{ohm}. \\ 2\rho_h = (.126\ \text{ohm}.) \end{cases}$

Strain.	$e \times 10^3$, temporary.					$e \times 10^3$, permanent.
	Throw.	1m	2m	3m	4m	
0	.....	.....	.....	.....	.....	+16
I	—17	+46	60	67	70	+79
II	—10	+24	28	29	.....	+95
III	.....	.....	.....	.....	.....	.....
IV	.....	.....	.....	.....	.....	.....
0	.....	.....	.....	.....	.....	—56
I	—33	—17	— 6	—3	—1	—40
II	— 4	+ 7	+14	.....	.....	—23
III	— 6	+13	+14	.....	.....	— 6
IV	.....	.....	.....	.....	.....	.....

Extension per pull = ·05
Radial contraction per pull = ...
Mean permanent potential increase per pull = + ·027

TABLE 27.—*Miscellaneous work.*

Copper wire, water.

Strain.	$e \times 10^3$, temporary.					$e \times 10^3$, permanent.
	Throw.	1m	2m	3m	4m	
0.....	.....	.....	.....	.....	.....	+15
Jerk.....	—42	+ 2	.....	.....	.....	+ 4
Jerk.....	—35	— 4	.....	.....	.....	+ 2
I, II	+29	+28	+29	+34	.....	+27
III, IV	+13	+ 9	+ 7	+ 8	.....	+28

Extension per pull = ·05
Radial contraction per pull = ·03
Potential increase per pull = ·015

Digitized by Google

TABLE 27.—*Miscellaneous work*—Continued.

Brass wire, water.

Strain.	$e \times 10^3$, temporary.					$e \times 10^3$, permanent.
	Throw.	1m	2m	3m	4m	
0						— 8
Jerk	—21					—25
Jerk	—35					—29
Jerk	—17					—21
Rub						—10
Rub						— 6
Rub						— 9
0						— 6
I	+35	35	35	31	31	+25

Iron wire, water.

0						—40
Jerk	—42	—15	— 6	+ 2		—39
Jerk	—49	—28	— 6	+ 1		—36
Jerk	—45	—21	— 7			—36
After waiting						—18

German silver, $2\rho = .080^{cm}$. Zinc sulphate.

Strain.	$e \times 10^3$, permanent.	Strain.	$e \times 10^3$, permanent.
0	+13	0	—1
I	+ 7	I	—6
II	+ 0	II	—6
III	— 6	III	—6

EFFECTS CLASSIFIED.

45. Turning first to the permanent hydroelectric effect of traction, Tables 21 and 22 show increments of decidedly larger positive value than hold for iron in Table 20. The effect for copper in Table 23 is nearly zero, and for iron, Table 24, actually negative. Whatever the effect may be it is necessarily to be considered doubly specific, depending both on the metal and the liquid. Hence I made further investigations in Tables 25, 26, 27, by replacing zinc sulphate solution by distilled water. Here it is found that the permanent effect is decidedly less in magnitude for zinc sulphate than for water, from which a close relation of these phenomena and of polarization may be inferred. Moreover, the effect in case of water is by no means as regular as in the other case. In Table 25, for instance, the permanent points inclose an area of rhomboidal outline, showing that the effects of initial pulls are different in sign from those of final pulls. Again, copper, which in case of zinc sulphate is not charged by traction, shows a hydroelectric effect in case

Digitized by Google

of water comparable with that of other metals. Again the changes iron-water are excessively large. Irrespective of sign, the magnitude of the hydroelectric effect has increased with the diameter of the wires used.

Among results bearing on a later paragraph (§46) I may mention that the permanent effect of traction of iron in zinc-sulphate is sometimes positive and sometimes negative, depending on the qualities of the wire. Table 27 shows a specimen of German silver in which the permanent effect is negative.

I have given the temporary effects in their *absolute* values (increments) at consecutive times, independent of the potential of the wire. In case of German silver, of brass, of copper, these effects are distinctly positive, i. e., opposite in sign from the temporary effects for iron, which are invariably electro-negative both in the present instances (Tables 24, 26) and in Table 20.

DISCUSSION OF ERRORS.

46. Returning to the explanation suggested above (§ 43), it appears that in German silver, copper, and brass the effect of diminished capacity and of exposure of fresh surface,[1] due to stretching, both of which are positive, predominates over the negative effect of accidental jerking. In iron they do not so predominate. It is specially to be noticed that the permanent effect is entirely independent of the temporary effect. Inasmuch as the permanent effect is obtained by commutation (each electrode being alternately put to earth) the residuum of the temporary effect is discharged. From this it may be conjectured that the apparatus acts like a double condenser.

In Table 27 I give some data bearing on the probability of this explanation. The wires were adjusted in the usual way, but instead of being stretched they were only jerked by the action of the machine. In this case a negative temporary effect is obtained in all the metals, about of the same numerical order as the data of the earlier tables. Similar results follow after rubbing immersed parts of the wires.

Again, the temporary effect may be due to friction at the axle of the drum. But such an effect would discharge itself to earth, unless the wire and water act as a condenser. It would necessarily fall out of the permanent effect, for here the wires are alternately put to earth.

47. *Variable capacity.* If the wire be of the form of a cylinder of length l and radius r, its capacity is approximately

$$C = l / 2 \ln \frac{1}{r}.$$

Hence, since the charges are constant

$$Q = VC = V'C' \text{ or } V/V' = \log r / \log r'$$

whence it follows that (V_1' and V being identical)

$$V_1' = \frac{\log r'}{\log r - \log r'} (V - V') \quad \ldots \quad (1)$$

[1] This being at once acted on by the liquid, falls under the considerations made in text.

From this expression the polarization of the wire may be calculated from the difference of potential produced by traction. The data of Tables 20 to 27 then furnish the following values of V'. The subscripts attached to the symbols for metals refer to the number of the table.

TABLE 28.—*Digest.*

Metal.	Fe_1	Arg_2	Br_3	Cu_4	Fe_5	Br_6	Fe_7	Cu_8
log r/log r/r'	26	26	33	19	32	25	30	19
$\Delta V \times 10^3$	3×4	5×4	15×4	1×4	−3×4	±15×4	27×4	15×4
V_1'	+·31	+·52	+1·98	+·08	−·38	±1·50	+3·24	+1·14
	$ZnSO_4$					H_2O		

If the wire with its surrounding liquid acts like a condenser, of which the layer of polarizing gas (hydrogen) is the medium through which induction takes place, then the capacity is that of two concentric cylinders of radii r_2 and r_1, respectively, and the common length l. Here $C=\frac{1}{2}\frac{Kl}{ln\ r_2/r_1}$, or $C=\frac{r_1 l}{e}\left(1+\frac{e}{2r_1}\right)$, nearly, when $r_2-r_1=e$ and K, the specific inductive capacity of the layer of gas is taken as 1. Now, if we proceed as above, and consider the charge constant, an equation similar to (1) may be obtained by introducing some reasonable postulate relative to the thickness e of the polarizing gas. Suppose $e=$ constant; i. e., that before and after each pull the layer has not changed in thickness. Then $V/V'=(2r'+e)/(2r+e)$, or, approximately (V_2' and V' being identical),

$$V_2'=\frac{r}{r'-r}(V-V') \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Again, suppose the mass of gas to remain the same, so that $2\pi re=2\pi r'e'$. Then $V/V'=(2r'^2+er)/(2r^2+e)$, or, approximately (V_3' and V' identical),

$$V_3'=\frac{r^2}{r'^2-r^2}(V-V') \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Hence, Tables 1 to 8 furnish the following digest:

TABLE 29.—*Digest.*

Metal.	Fe_1	Arg_2	Br_3	Cu_4	Fe_5	Br_6	Fe_7	Cu_8
$r/(r'-r)$	39	42	71	38	67	51	57	38
V_2'	·12	·21	1·06	·04	−·20	±·76	1·54	·57
$r^2/(r'^2-r^2)$	75	77	136	72	127	100	110	72
V_3'	·22	·38	2·04	·07	−·38	±1·50	3·00	1·08
	$ZnSO_4$					H_2O		

In discriminating[1] between V_1, V_2, V_3, it is clear that the conditions

[1] The close analogy of a polarized voltameter and a doubled condenser was pointed out by Varley (Phil. Trans., vol. CXLI, p. 129, 1872) and others. The subject is minutely discussed in Wiedemann's Elektricität, vol. II, pp. 758 to 771. It may be observed that in equation (2) the increment of potential varies as the decrement of the wetted surface.

Digitized by Google

under which V_1 applies are not given, and that the maximum probability rests with V_2; but this quantity is not decidedly above the order of possible polarization for the cases under consideration. Hence, the permanent hydroelectric effect due to a change of the electro-positive quality of a metal by traction, is obscured beyond recognition by the unavoidable variations of polarization accompanying the experiment.

SINGLE WIRES.

48. Having thus failed to obtain reliable evidence from the hydroelectric experiments, I endeavored with some pains to discern a direct electrical effect (potential) due to the traction of an insulated wire. Here again I failed; for not only is the needle of Mascart's electrometer always in motion when connected with a train of insulted wire, but the effect of traction is friction at the points of fastening at the ends of the wire. This friction of the metal wire against the insulators is apt to evoke relatively powerful charges as compared with the true effect of traction. Particularly is this the case if during traction the distended wire begins to loosen. By soldering loops at the ends of the wire the frictional disturbance can be reduced to a minimum, without, however, furnishing definite evidence of a purely traction effect.

SUMMARY.

49. In the above paragraphs I have endeavored to refer the very definite hydroelectric results obtained to the simplest explanation at hand. But it is necessary to bear in mind that the phenomena are so largely beyond the observer's control that an exhaustive experimental discussion is out of the question. It would be unwise, therefore, to lose sight of other points of view from which they may have a direct bearing on the real question in hand, viz., the possibility of molecular change in a metal corresponding to each change of strain imparted to it. The question is steadily gaining in probability. Osmond, after making an elaborate pyrometric study of the conditions under which Gore's phenomenon occurs in iron, postulates the existence of an α and a β variety of iron. These varieties when cold may be distinguished physically by their difference in hardness. Moreover, β-iron, besides being produced spontaneously out of α-iron, above a certain temperature in red heat, may also be produced in small quantity by straining α-iron at ordinary temperatures. I pointed out that such a hypothesis involves the occurrence of α and β varieties of most metals, even when no such criterion as is given by Gore's phenomenon is observable. Quite recently Mr. Carus-Wilson,[1] from experiments made on the viscosity of strained steel, summarizes his experience in favor of Osmond's[2] view. Unfortunately, the well known effects of strain on the thermo-

[1] Carus-Wilson, Nature, vol. 41, 1890, p. 213.

[2] Osmond, Annales des Mines, July–August, 1888; Mém. de l'artillerie de la Marine, Paris, 1888. p. 4.

Digitized by Google

electric quality and on the resistance of metals are not at once interpretable, except, perhaps, in so far as they are accompanied by hysteresis (Cohn, Warburg, Ewing, Schumann). The ion theories of metallic electrical conduction now coming into vogue (J. J. Thomson, Giese[1]), conditioned as they must be by the occurrence of marked molecular instability in metals, are steps in the same direction. I will therefore merely point out, in concluding, that the simple explanations given above for the temporary effect, which was found consistently negative at first in iron, and consistently positive in all the other metals, is not satisfactory. It is permissible to regard it as the direct result of a change of molecule due to straining; for it is precisely in the first stages of the temporary effect that evidence for such molecular change may reasonably be sought.[2]

[1] Giese. Wied. Ann. vol. 37, 1889, p. 576.

[2] Cf. Rowland and Bell (loc. cit.), who are obliged to base their inferences on the temporary hydroelectric effect of magnetization. In all problems of this character it is necessary to distinguish between the positional stability and the chemical stability of a molecule. It does not follow that if the former quality is increased the latter will also be, for a chemical solvent does not pick up molecules bodily, but by disintegrating them. In certain experiments on the isothermal electromotive force of a Daniell between 10 and 1,800 atmospheres, I will indicate this further.

Digitized by Google

CHAPTER VI.

THE SECULAR ANNEALING OF COLD HARD STEEL.

INTRODUCTORY.

Inasmuch as the method I used for testing Maxwell's theory of the viscosity of solids contains a proof of that theory a fortiori, I did not distinguish in that paper[1] between a break-up of configurations of molecular wholes and the more intensified break-up in which the integrity of the molecule itself is invaded. The experimental distinction is not always easy. If, for instance, I dissolve certain solids (pitch, say, in turpentine) I may produce a continuous series of viscous fluids; but the molecular mechanism by which this is brought about can not in the present state of our knowledge of solution be said to be known. I may cite another striking example, ebonite, which above 100° loses vicosity at an exceedingly rapid rate by mere heating; but, again, the molecular change which produces the viscous effect is obscure. And so generally in less remarkable experiments.[2] In the case of metals, it appears that those elements whose molecules are least stable and possibly monatomic[3] (K, Na, etc.) are of a soapy consistency, so that here vicosity (Nachwirkung) and permanent set can hardly be distinguished. In general it appears that metallic permanent set is physical manifestation of looseness of molecular structure. If, as in the case of annealing glass-hard steel, the rigid arch (say) of molecular wholes breaks up because one or more of the molecules, the stones of that arch, disintegrate, and if the decomposition be of a kind that the débris may be chemically recognized, then, by coordinating the viscous and the chemical observations, I obtain a fairly good notion of the molecular mechanism which has produced the viscous effect. This is the method I applied to prove Maxwell's theory. But partial disintegration or reconstruction of molecules may easily be conceived to occur in such a way as to escape detection altogether or at least to escape detection as much as does a break-up of configurations of molecular wholes. It may, I think, be reasonably supposed that the solid molecule is of the form M_n, in which n is variable; and any given value of n will occur

[1] Philosophical Magazine, London, August, 1888.

[2] Cf. Lothar Meyer (Die modernen Theorien der Chemie, Breslau, 1884, chapter VIII,) on solid molecular structure.

[3] Ibid. chapter XVI, sec. 308, etc.

Digitized by Google

less frequently according as it is proportionately greater or less than the mean or typical value of n for the solid. The effect of strain, of change of strain, or even of long continued secular subsidence is merely to vary the distribution of molecules M_n, so that the general properties of any observably finite part of the solid do not change.[1]

I will adduce other points of view in succeeding papers; but the suggestions stated are sufficient, I think, to show the importance of discerning whether the cause of viscous deformation in tempered steel is the type of viscous deformation in general or whether, in using the phenomena of annealing steel to test Maxwell's theory, I have merely interpreted the exception to prove the rule. The result of such an investigation, besides throwing light on the structure of solid matter, must ultimately lead to inferences bearing directly on the questions of fusion, solution, and volatilization.

RESULTS FOR HOMOGENEITY OF RODS.

51. This inquiry, being essentially a comparison of detail, will consume much time before it can be brought to an issue; and, as the individual parts of my work have led to results which are of interest[2] apart from the purposes to which I hope ultimately to apply them, it is perhaps best to communicate the data separately. The following results on the secular annealing of cold glass-hard steel essentially sustain the inferences of my last paper. They were omitted because of the space occupied by the discussions there given. The rods to which the data refer are Stubbs's best steel, tempered in a special apparatus,[3] by aid of which the wire heated to redness electrically is suddenly whipped into water. Freshly quenched samples of wire showed specific resistances (0° C.) as high as $s=48$. All the rods were tested for longitudinal uniformity of temper by stepping off, as it were, the resistance of lengths of 2^{cm}. each with each of the consecutive 3^{cm}. of wire. The total length being about 30^{cm}., eight measurements were thus made. A device utilizing Matthiessen and Hockin's method, and provided with a suitable rider, enabled me to do this with reasonable accuracy. Table 30 contains the results as obtained with three batches of wire, of the diameters

---

[1] In other words, it is here supposed that the assumption of solid state has not thoroughly eliminated liquid or even the gaseous molecule and that it has, on the other hand, produced molecules of ultra-solid complexity. Here I touch the keynote of certain difficulties in my mind against conceiving the solid molecule as a uniformly distinct whole, capable of rotation (Kohlrausch viscosity) and capable of translation from strained to isotropic configuration (Maxwell viscosity). I look upon it as a more cumbersome thing, which may under favorable conditions even lose its identity, and which, while undergoing the motions stated, comes into serious conflict with contiguous molecules. Such a view, even if it be mere surmise (excepting the case of hard steel discussed), is a suggestive working hypothesis; for it seems broad enough to enable me to circumscribe the true phenomenon by clipping the postulate. This is the general endeavor of my present work.

[2] It is well known that experiments on the secular changes of metals are being made at Glasgow by Bottomley. Cf. Brit. Assoc. Report, 1888, p. 537.

[3] Bull. U. S. Geol. Survey, No. 14, 1885, p. 29. My present apparatus is horizontal in form and enables me to quench the wires from any degree of red heat in water or other liquid at any desirable temperature. See Fig. 5, p. 7, Bull. No. 73, 1891.

Digitized by Google

$2\rho = \cdot 081^{cm.}$, $\cdot 044^{cm.}$, and $\cdot 127^{cm.}$, respectively. The approximate resistance (microhms) of the $2^{cm.}$ of length is designated by r.

TABLE 30.—*Longitudinal uniformity of temper of the steel rods.—Variation from mean, in terms of the electrical interval, hard-soft.*

No. 1. $r=18500$.	No. 2. 18500.	No. 3. 17700.	No. 4. 17600.	No. 5. 17700.	No. 6. 18500.	No. 7. 18400.	No. 8. 18500.	No. 9. 17400.	No. 10. 17900.
·002	·002	·000	·003	·010	·005	·004	·009	·032	·006
4	— 2	0	— 2	10	— 3	1	— 11	18	— 6
2	— 2	5	— 2	— 7	— 7	1	— 11	11	2
— 1	2	5	7	— 2	5	7	5	— 46	2
— 6	— 2	5	— 2	6	1	7	— 3	— 64	— 2
4	— 6	— 13	— 6	— 7	— 2	— 5	5	— 16	— 6
1	— 2	0	— 2	— 11	— 7	— 8	5	23	10
— 4	10	— 4	3	2	9	— 5	1	41	— 6

No. 11. $r=61200$.	No. 12. 60600.	No. 13. 61200.	No. 14. 60200.	No. 15. 62000.	No. 16. 6800.	No. 17. 6760.	No. 18. 6580.	No. 19. 7290.	No. 20. 6850.
·007	— ·007	— ·003	·023	·016	— ·006	·001	— ·009	·001	— ·013
2	— 1	— 3	— 1	— 1	— 2	1	7	1	— 26
— 7	— 4	— 3	1	— 3	3	5	15	10	4
— 10	— 7	— 10	— 7	— 9	— 2	— 3	8	10	17
1	4	5	— 4	2	— 2	— 3	— 1	14	13
1	— 1	— 3	— 4	— 12	— 2	1	11	— 11	13
1	4	8	— 4	— 1	3	— 3	— 5	— 11	— 13
10	13	8	— 4	8	7	1	— 20	— 11	4

With the exception of No. 9, the variations are, as a rule, well within 1 per cent. of the electrical value of the interval hard-soft. Where the resistance is larger or smaller than the mean value, it is possible that the parts were accidentally splashed by the water immediately before quenching or quenched at a different degree of red heat. But, inasmuch as the series of measurements for each rod takes some time and as the effective resistances are necessarily small, I believe that the rods are even more homogeneous than Table 1 indicates; for the errors introduced by variations of temperature, by the difficulty of clamping the thin, very brittle rods (soldering would change the temper enormously), and by other inconveniences of manipulation, are by no means negligible. Hence the degree of homogeneity found may be considered quite satisfactory.

MASS CONSTANTS OF RODS.

52. In Table 31 I give the mass m, length l, and density at 0° C., Δ_0, of some of the rods. The latter datum is essential for the determination of the sections. I shall also use it in the future in determining the secular volume-changes of these wires. Rods Nos. 11 to 15 are too thin for direct measurement. Hence a mean value of Δ_0 was here assumed. I may add that in the soft state the density of these rods is about $\Delta_0 = 7{\cdot}80$.

Digitized by Google

TABLE 31.—*Mass constants of the glass-hard steel rods, June, 1885.*

No.	m	l	Δ_0	No.	m	l	Δ_0
	g.	*centim.*	*g/cm².*		*g.*	*centim.*	*g/cm².*
1	·9910	24·95	7·710	11	·3257	27·94	
2	·9544	24·02	7·689	12	·3322	28·30	
3	·9976	25·25	7·708	13	·3170	27·20	
4	1·0483	26·30	7·705	14	·2889	24·85	
5	1·0079	25·46	7·703	15	·3004	26·07	
6	1·0243	25·80	7·687	16	2·4713	25·63	7·676
7	1·0089	25·47	7·670	17	2·4857	25·70	7·671
8	1·0074	25·50	7·682	18	2·1043	22·50	7·544
9	1·0666	26·68	7·726	19	2·5327	26·06	7·685
10	1·0293	25·58	7·719	20	2·3557	24·40	7·653

53. *Electrical constants of rods.*—Table 32 contains the electrical constants of these rods; r_t being the observed resistance per centimeter at $t°$, α the temperature coefficient, and s_0 the corresponding specific resistance at 0° C. The wires were quenched on June 1 and 2, 1885, and the measurements made at the time given, only a few days after hardening. Sections and radius are given under q and ρ respectively. In most cases q is individually determined.

TABLE 32.—*Specific resistance of the glass-hard steel rods, measured June 4 and 8, 1885.*

[Effective length, 20 cm. to 26 cm.]

No.	$q\times10^6$	$2\rho\times10^3$	r_t	t	$\alpha\times10^3$	s_0
	Centim.²	*Centim.*	*Microhm.*	° *C.*		*Microhm.*
1	5152	80·6	9260	27·5	1·5	46·0
2	5168		9250	27·8	1·5	46·0
3	5126		8870	28·3	1·6	43·7
4	5173		8810	27·0	1·6	43·8
5	5139		8840	27·2	1·6	43·7
6	5165		9260	26·8	1·5	46·1
7	5164		9200	27·0	1·5	45·8
8	5143		9260	26·3	1·5	46·0
9	5174		8720	26·3	1·5	43·6
10	5214		8950	25·1	1·5	45·1
11	1520	44	30670	25·2	1·5	45·1
12	1520		30320	25·3	1·6	44·4
13	1520		30620	24·8	1·5	45·0
14	1520		30080	25·5	1·6	44·1
15	1520		30990	26·8	1·5	45·4
16	12560	126·5	3400	26·4	1·7	41·0
17	12610		3382	26·4	1·7	41·0
18	12400		4144	26·6	1·5	49·5
19	12650		3643	26·7	1·6	44·3
20	12620		3427	27·2	1·7	41·5

Finally, Table 33 contains the electrical constants of these rods made about thirty-seven months after the first measurement. It also con-

Digitized by Google

tains the variations, Δr_t, of the resistance per centimeter, as well as the variations, Δs_0, of the specific resistance. It will be seen that Δs_0 is negative throughout, whereas the effect of atmospheric influence and the unavoidable abrasion in cleaning the surfaces of the wires before measurement would produce a positive error. The same bridge and the same standards of German silver are used both in the measurements of Table 32 and of Table 33. The fact that the wires differ in diameter, and therefore vary largely in resistance, is a guarantee against the effect of differences of sectional errors of the bridge wire. Again, although Δs_0 is essentially the difference of secular change between the steel-wire and the German-silver standards, the fact that two standards (1·0 ohm and 0·1, respectively) were used at least partially eliminates the error due to variations in the standards. Moreover, the electrical effects of corresponding variations of temper (steel) and of the drawn strain which the German silver may possibly carry are enormously different. For instance, if glass-hard steel is boiled long enough the change of resistance may reach 12 per cent and more. The effect of boiling German silver is of the order of some tenths per cent.[1] Hence I apprehend no serious error in ascribing the whole of the observed variation of s_0 in Table 33 to secular annealing of the glass-hard steel rods under experiment.

TABLE 33.—*Specific resistance of the glass-hard steel rods measured July 9, 1883, and the secular variation.*

[q as in Table 32; effective length, about 23 cm.]

No.	$2\rho\times10^6$	r_t	t	Δr_t	$\alpha\times10^3$	s	Δs_0
	Centim.	*Microhm.*	° *C.*	*Microhm.*		*Microhm.*	*Microhm.*
1	80·6	8460	28	—790	1·7	41·7	— 4·2
2		8430		—820		41·7	— 4·3
3		8010		—860		39·3	— 4·4
4		7950		—850		39·3	— 4·4
5		8010		—830		39·4	— 4·3
6		8460		—800		42·0	— 4·1
7		8400		—800		41·5	— 4·3
8		8510		—750		41·9	— 4·1
9		7920		—800		39·2	— 4·3
10		8170		—780		40·8	— 4·3
11	44	27860	29	—2810	1·7	40·5	— 4·6
12		27710		—2610		40·3	— 4·2
13		28000		—2620		40·7	— 4·3
14		27490		—2590		40·0	— 4·1
15		28400		—2590		41·3	— 4·1
16	126·5	2807	29	— 590	2·1	33·3	— 7·7
17		2807		— 570		33·4	— 7·5
19		2830		— 810		33·8	—10·5
20		2808		— 620		33·5	— 8·0

[1] Cf. Bulletin U. S. Geol. Surv. No. 14, p. 94.

Digitized by Google

SUMMARY.

54. Summarizing the results of Tables 32 and 33, it appears that during the 37 months between the two series of observations the specific resistance of the rods has fallen from 46·5 to 42·5 in case of the thin rods (diameter $<$·08 centim.) and from 43·7 to 35·4 in the case case of the thicker rods (diameter .13^{cm}.). Hence the variations are a decrement of specific resistance amounting to some 10 or even 20 per cent in the extreme cases. This may be stated succinctly as follows: Mean atmospheric temperature acting on freshly quenched steel for a period of years produces a diminution of hardness about equal to that of 100° C. acting for a period of hours. Similar results have been suspected for magnetic measurements; but such results are very much less easily interpretable than the electrical data of Table 33; for earlier measurements prove conclusively that the electrical variations in question are sufficient evidence for the occurrence of concomitant changes of hardness, volume, carburation, etc. Finally, the above results show that the method of tempering magnets proposed by Dr. Strouhal and myself warrants the steel against secular structural instability for a time certainly exceeding three years.

Digitized by Google

CHAPTER VII.

THE VISCOSITY OF ELECTROLYZING GLASS.

APPARATUS.

55. The apparatus by which I endeavored to throw light on this question is represented in Figs. 5 and 6. As regards principles involved they are identical with my earlier apparatus. Hot and cold parts of a glass tube *abc* are counter twisted. To accomplish this with least amount of breakage, the ends of the tube are clamped between parallel thin boards, *A* and *B*, and cemented with mastic. *A* being fixed, torsion is applied at *B*. The amount of this is never very large and it may be gradually increased by a screw adjustment acting against a radial lever in connection with *B*. The experiment is troublesome, as the brittle glass tubes frequently break. To heat any part of *abc*, it is inclosed in one of my boiling tubes, *dddd*, containing mercury, *GG*, which may be kept in ebullition by the ring burner *RR*. The mirror *M*, adjustably fixed between hot and cold parts of *abc*, registers the amount of viscous deformation. The method of passing current through the tubes is different in the two figures. The more complicated arrangement in Fig. 5 secures greater constancy of temperature along cold parts of the tube, all hot parts being above. The core of the tube *abc* is partly filled with sodium amalgam, as shown at *ff''f'*, and one terminal of a dynamo, or a Grove battery, connects with this at *f'*. Again the tube *abc* is surrounded near its middle by a funnel-shaped cup *FF*, also containing sodium amalgam. This can be drawn up into the central tube *gg*, closed above by aid of an exhaust pipe attached at *E*. The other terminal of the dynamo is in connection with *F*, as shown at *h*. When this current is made, it therefore passes in at *f'*, into the core of *abc*, *through abc*, into the core of *gg*, into the cup *F*, and thence back to the dynamo. In Fig. 6 the mechanism is much simpler. The tube *abc* is fixed in *dddd* with a plug of plaster of paris, *p*, and *abc* is immediately surrounded by the ebullition mercury *G*. The current as before passes in at *f'*, through the walls of *abc* into *G*, and thence via *h* to the dynamo. Some care must here be taken in screening *M*, the mirror. In general a number of screens are to be disposed in ways which easily suggest themselves.

Digitized by Google

RESULTS.

56. In Table 34 I have given my first results with the apparatus, Fig. 5. A battery of 10 Grove cells was used as a source of current. Warburg's[1] device of sodium amalgam electrodes was not known to me at the time, and I here used simple mercury for the purpose. The current in this case was originally about ·01 ampère, but fell off rapidly to ·001 ampère, and finally vanished altogether. The results of the table were obtained during the period of current; and although in later experiments I applied both dynamo and intermittent currents, the effects were nil. Warburg (loc. cit.) has shown that glass partially electrolyzed is a condenser of very measurable capacity, the dielectric being filmy silica. In the table, L is the length of the tube, a the length of the hot part (temperature $\theta=360°$), and k the length of the cold part (temperature $\theta'=25°$), respectively. The mirror is at a distance l' above the lower end. The rate of twist is τ. Finally ρ_1 is the outer radius, ρ_2 the inner radius, q the material section of the tube. To understand the progress of the experiment it is necessary to consult the time column. The viscous datum has the same meaning as above, except that in the present instance it refers to relatively very large sections q. Hence the smaller amounts of viscous motion observed. Moreover, in case of glass, τ can only be chosen very small, if liability to rupture is to be avoided.

In Table 35 the dimensions of apparatus are nearly the same as in Table 34. Twist, however, was considerably increased, almost sufficiently to produce rupture; and, moreover, sodium amalgam is here employed. The result was a current of the uniform intensity of 0·02 ampère traversing the glass.

A number of other similar experiments were made, all of which led to

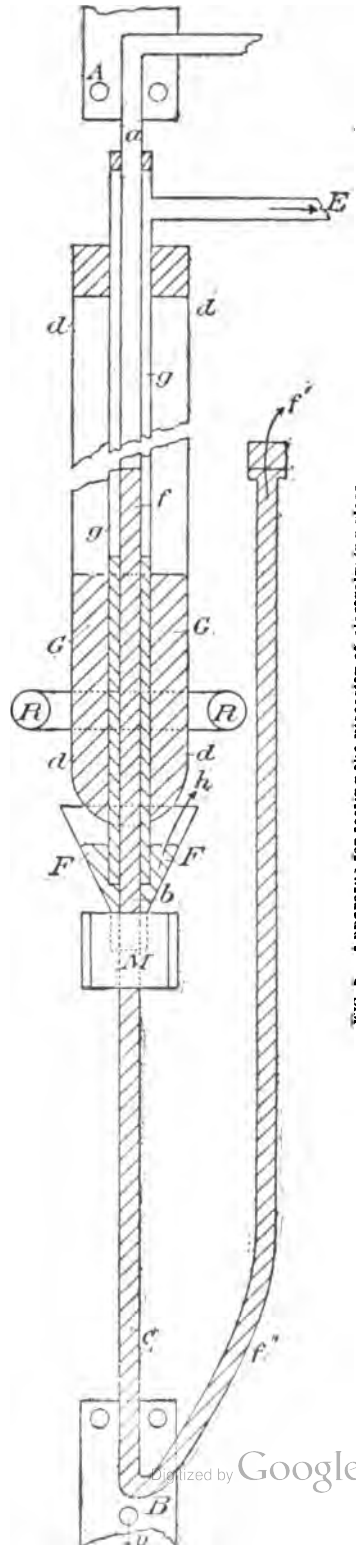


FIG. 5.—Apparatus for testing the viscosity of electrolyzing glass.

[1] Warburg: Wied Ann., xxi, p. 622, 1884.

Digitized by Google

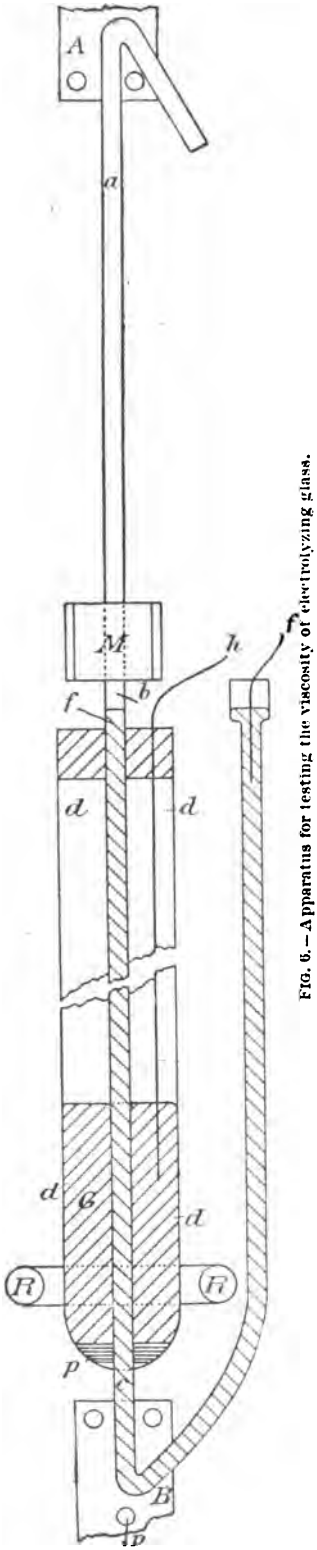


FIG. 6.—Apparatus for testing the viscosity of electrolyzing glass.

results of the same indecisive character. With currents of the small intensity given ($<0{\cdot}02$ ampère), viscous effects can hardly be expected to be discernible within the small interval of observation. If large intervals were chosen constancy of temperature in case of the apparatus given could not be guaranteed. The results of Table 34 are such as to suggest the actual occurrence of a viscous effect of current. This is not substantiated by Table 35. I can not, however, regard these results as conclusively negative. It is difficult to avoid contact between the tubes *abc* and *gg* in Figure 5, without choosing for the latter a tube inconveniently wide. For this reason I abandoned this apparatus and made the further experimentation with that of Fig. 6. It will not be necessary to give the data in full. They are again indecisive, because the viscous motion is too slight for sharp discrimination. The method of work being such that the rate of twist was successively increased until rupture finally ensued, it appears that the experiment was carried quite up to the limits of attainable accuracy. In Table 36 I indicate the nature of the results for the case of an extreme intensity of twist, after which the tube broke.

INFERENCES.

57. To summarize: When the available current can not be increased beyond the small datum given in the tables, it is improbable that viscous effect of larger value than one or more per cent is possible; but, to discern such small differences, the viscous motion must be very much more rapid. In other words, very *thin-walled* tubes of small caliber are to be chosen. In such a case the intensity of current as well as the viscous deformation will be effectively increased. The difficulties of experiment with thin tubes are very great, so that I am obliged to abandon further research at present.

In conclusion I may insert some remarks relative to the conditions under which increased viscous motion during the passage of current may be expected. Prof. J. J.

Digitized by Google

Thomson and Mr. Newell[1] have shown that for small electromotive forces the leakage in case of a liquid dielectric obeys Ohm's law, thus indicating that the molecular break-up was merely directed, but not produced, by electromotive force. On the other hand Quincke, using much larger electromotive forces, finds that the leakage, cæteris paribus, takes place according to some higher power than the first of electromotive force. Hence in this case the electric field is actually instrumental in dissociating molecules.[2] Since Ohm's law is rigorously obeyed in electrolytes, it is questionable whether electromotive forces of ordinary value can produce viscous effects even in case of solid electrolytes, for the rate of break-up is not thereby increased.

TABLE 34.—*Viscosity of electrolyzing glass. Hg terminals.*

$L=95^{cm}$; $a=15^{cm}$; $k=45^{cm}$; $\left\{\begin{matrix}2\rho_1=0{\cdot}40^{cm}\\2\rho_2=0{\cdot}80^{cm}\end{matrix}\right.$
$l=40^{cm}$; $\theta=36°$; $b'=25°$
$\tau=0{\cdot}003$

Time.	Current.	$\frac{\phi-\phi'}{\tau}\times10^3$	Time.	Current.	$\frac{\phi-\phi'}{\tau}\times10^3$
12h 10m		0·0	12h 35m	on	82·3
17	off	18·0	38	on	87·3
20	off	29·7	38	off	87·3
23	off	43·0	41	off	90·7
23	on	43·0	41	on	90·3
26	on	56·3	44	on	92·3
26	off	57·0	44	off	93·0
29	off	67·0	47	off	94·3
29	on	68·3	47	on	94·3
32	on	78·3	50	on	96·3
32	off	77·7			
35	off	82·3			

Now, unless the electric field be of sufficient intensity to produce a marked change in the motion, i. e., the free path of the ion, it is not probable that such a field will modify the viscosity of glass. Fields of small intensity can not increase the molecular instability. Hence the experiments of the next chapter, the character of which is nearly the converse of the present experiments, are better calculated to show positive results.

TABLE 35.—*Viscosity of electrolyzing glass. Na-amalgam terminals.*

Time.	Current.	$\frac{\phi-\phi'}{\tau}\times10^3$	Time.	Current.	$\frac{\phi-\phi'}{\tau}\times10^3$
3h 20m		0·0	3h 51m	on	9·2
32	off	5·2	52	on	9·4
41	off	6·8	52	off	9·4
45	off	8·4	53	off	9·6
47	off	8·8	53	on	9·6
49	off	8·4	54	on	9·6
49	on	8·4	54	off	9·6
50	on	9·0	55	off	9·6
50	off	9·0			
51	off	9·2			

[1] Thomson & Newell: Proc. Roy. Soc., XLII, p. 410.
[2] Cf. J. J. Thomson: Application of dynamics to physics and chemistry, p. 292.

Digitized by Google

TABLE 36.—*Viscosity of electrolyzing glass. Na-amalgam terminals.*

$\theta = 360°$. $2\rho_1 = \cdot 53^{cm}$. $a = 15^{cm}$.
$\theta' = 25°$. $2\rho_2 = \cdot 40^{cm}$. $L = 95^{cm}$.
Current, 0.02 ampère.

Time.	Current.	$\frac{\phi - \phi'}{\tau} \times 10^3$	Time.	Current.	$\frac{\phi - \phi'}{\tau} \times 10^3$
34m ... 36.....	off	1·0	46..... 48.....	off	3·8
36..... 38.....	on	1·6	48..... 50.....	on	4·8
38..... 40.....	off	1·8	50..... 52.....	off	5·2
40..... 42.....	on	2·4	52..... 54.....	on	6·0
42..... 44.....	off	2·6	54..... 56.....	off	6·8
44..... 46.....	on	3·2	56..... 58.....	on	7.6

Digitized by Google

CHAPTER VIII.

THE ELECTRICAL RESISTANCE OF STRESSED GLASS.

INTRODUCTORY.

58. The thermal relations of the resistance of glass, originally studied by Buff,[1] have more recently been made the subject of research in memoirs by Beetz,[2] Foussereau,[3] Perry,[4] Thomas Gray,[5] and others. Warburg's[6] experiments, however, throw new light on the inquiry, by showing that the apparent polarization evoked by the passage of current is due to a layer of nonconducting silica depositing at the anode. If this be continually dissolved by an electrode of sodium amalgam, the apparent polarization is so far removed that an almost constant current may be kept up indefinitely. If the film be not removed, conduction soon ceases and the glass behaves like a condenser of measurable capacity.

The effect of temperature on the conductivity of glass has thus been mapped out with considerable detail, and it will be superfluous to add new data in the following chapter. I purpose therefore to confine myself narrowly to the effects of stress[7] on electrolyzing glass, kept as nearly as practicable at different constant temperatures between 100° and 360°.

APPARATUS.

59. The apparatus for these measurements are shown in Figs. 7, 8, 9, 10, 11. Figs. 7 and 8 are simpler and adapted to 360° and 100° respectively. Figs. 9 and 10 are intended for experiments with aniline (186°) or other nonconducting fluid, boiling at higher temperatures; and the last apparatus, Figs. 10, 11, are differential in kind.

As before, the ends of the tube *abc* (Fig. 7) to be operated upon are bent hook-shaped, and then fastened by screws and resinous cement between

---

[1] Buff: Lieb. Ann., vol. xc, 1854, p. 257.

[2] Beetz: Pogg. Ann., Jubelband, 1874, p. 23.

[3] Foussereau: Jour. de phys., II, vol. xi, 1883, p. 254.

[4] Perry: Proc. Roy. Soc., vol. xxiii, 1875, p. 468.

[5] T. Gray: Proc. Roy. Soc., vol. xxxiv, 1883, p. 199.

[6] Warburg: Wied. Ann., vol. xxi, 1884, p. 622; ib., xxxv, 1888, p. 455.

[7] Reference may here be made to J. and P. Curie (C. R., vol. 91, pp. 294, 383; vol. 92, p. 350, 1881; vol. 93, p. 1137, 1881), and to Hankel (Wied. Ann., p. 640, 1881), who show that in certain hemihedral crystals longitudinal compression is accompanied by the manifestation of electromotive force. Curie's very recent work is summarized in the Beiblätter, vol. 12, p. 857 to 867, 1888.

Digitized by Google

slabs of wood *A* and *B*. The upper one is fixed; the lower, *B*, provided with a hook from which a scale pan may be hung. In the experiments made, the load *P* was gradually increased as far as 20 kg. To heat the tube *abc*, and thus promote conduction, I used a ring burner *RR*, as before. *GG*, the ebullition liquid (here mercury), is contained in the boiling tube *d*, to the bottom of which the experimental tube *abc* is cemented with plaster of paris. Glass is electrically so sensitive to changes of temperature near 300°, that great care must be taken to keep the flame of the burner constant, and the ring is to be fixed in position relatively to the tube. Any disturbance of this symmetry during loading produces a periodic thermal error, the effect of which may be excessively large as compared with the stress effect to be measured. Finally, the current when made passes into the mercury within the tube *abc* at *f'*, then through the walls of the tube into the ebullition liquid *G*, and thence, via *h*, back to the battery. At 360° the resistance of this arrangement was less than 200 ohms, so that aside from temperature fluctuations the measurement is easy. With a single Daniell and a mirror galvanometer, the current observed is sufficiently constant to admit of direct measurement. From this the resistance may be deduced. When the liquid boils violently, resistance is variable, probably from the fact that a film[1] of mercury vapor of variable thickness envelops the metal and interferes with the uniformity of contact. The resistance for this case is larger, even twice as large, as when the mercury is at incipient ebullition. When the apparatus is loaded and unloaded alternately, relatively long and regular fluctuations of temperature are of no disturbing effect, the stress effect being superposed on the long undulation.

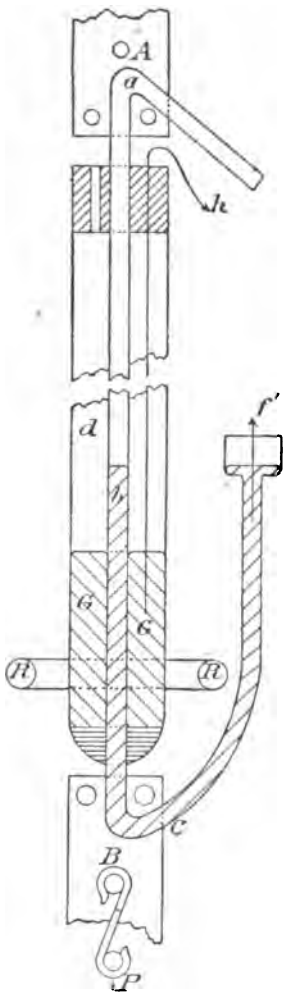


FIG. 7.—Apparatus for testing the viscosity of stressed glass.

EXPERIMENTS.

60. *Data for 350°.*—The scale deflections under the stated conditions are given below. From the many data I will select those of later date, these results being less liable to inaccuracy than the earlier data.

[1] I have thought of using this observation as a boiling-point criterion.

Digitized by Google

TABLE 37.—*Resistance of glass across the lines of stress.*

[$\theta = 350°$. $2\rho_1 = \cdot53^{cm}$. $2\rho_2 = \cdot40^{cm}$. Resistance, 500 ohms.]

Time.	Load.	Deflection.	Time.	Load.	Deflection.
h. m.	*kg.*	*cm.*	*m.*	*kg.*	*cm.*
2 8	0	5·70	29	0	5·10
10	0	5·40	31	0	4·90
12	0	5·20	32	5	4·60
12	5	5·10	34	5	4·60
13	5	5·10	36	5	4·65
15	5	5·10	38	0	5·10
16	0	4·85	40	0	5·60
18	0	4·55	42	0	5·90
20	0	4·28	43	5	5·80
22	5	4·40	46	5	5·30
26	5	5·40	47	7	5·25
27	0	5·35	51	7	5·00

Plainly the chief fluctuations here observed are due to temperature; but whatever the stress effect may be, its amount can not exceed a few per cent of the resistance of the glass sample. This appears quite as clearly in other results of the same kind, which need not be summarized here.

61. *Data for 100°.*—In consequence of the thermal discrepancies enumerated, I made the next experiments at 100° in a steam bath. The resistance encountered under these circumstances is, of course, very large. I measured it at about 20,000,000 ohms in case of the apparatus, Fig. 8. Here the tube to be stretched, *abc*, is surrounded by a wider tube, *gg*, closed above and below. Both tubes contain sodium amalgam, protected from moisture[1] by a layer of paraffin, *m*. Steam enters at the top and is discharged at *S*, so that the apparatus is drained of condensed water. In other respects the present apparatus resembles the above. The scale pan is attached at *P*. The results for this case are much more uniform. I give the following example:

TABLE 38.—*Resistance of stressed glass at 100°.*

[$2\rho_1 = \cdot53^{cm}$. $2\rho_2 = \cdot40^{cm}$. $l = 15^{cm}$. Resistance, 20 megohms, approximately.]

Time.	Load.	Deflection.	Mean.	Time.	Load.	Deflection.	Mean.
h. m.	*kg.*	*cm.*	*cm.*	*m.*	*kg.*	*cm.*	*cm.*
10 50	0	5·50		12	20	5·35	
53	0	5·45		14	20	5·35	
55	0	5·25		17	20	5·40	5·36
60	0	5·33		20	20	5.33	
11 07	0	5·30	5·30	21	21	5·38	
10	0	5·28		23	21	5·37	
				Tube breaks.			

[1] If *gg* contains the kathode, it may be filled with mercury instead of amalgam.

Digitized by Google

In these results the resistance, after attaining a constant value, decreases by about 1 per cent when the load is added. It can not, however, be affirmed with certainty that this decrement is the true electrical effect of the stress increment. All I have done is to narrow down its value to the order of 1 per cent.

62. *Data for 185°.*—My next experiment was made with aniline. The

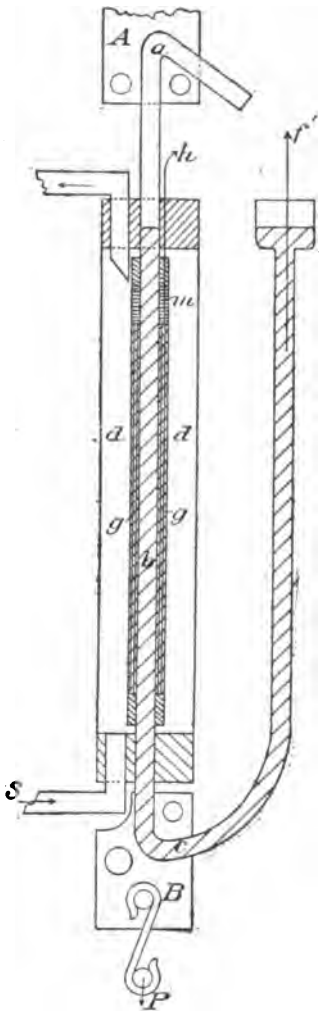


FIG. 8.—Apparatus for testing the viscosity of stressed glass.

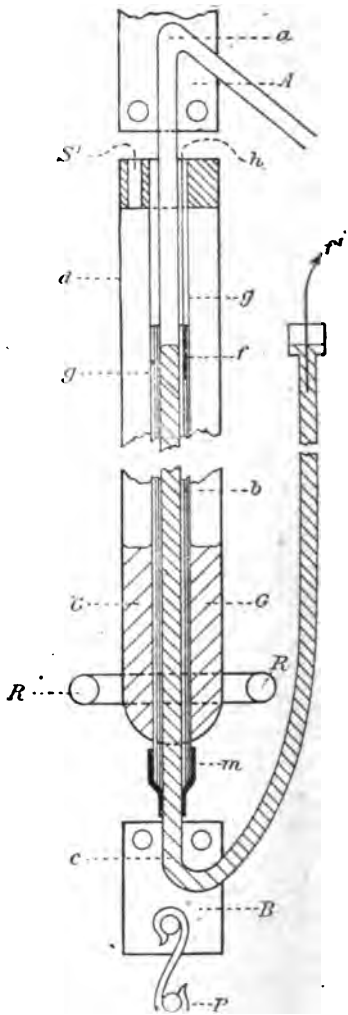


FIG. 9.—Apparatus for testing the viscosity of stressed glass

apparatus is shown in Fig. 9. Similar parts are lettered as in the preceding figures. The aniline is contained in the boiling tube *d*, *g*. The experimental tube *abc* being tied to the fixed central tube *gg* of the apparatus by a piece of rubber tubing, *m*, it is easy to surround both the inside and outside of *abc* with mercury. Current passes in at *f'* and

Digitized by Google

out at *h*. Ebullition is kept up with sufficient intensity to just fill the tube *d* with aniline vapor, which condenses in the exit tube *S'*, and then runs back. Two Grove cells were found sufficient for the experiment, the observed resistance for this case being about 60,000 ohms.

TABLE 39.—*Resistance of stressed glass.*

[$2\rho_1 = \cdot 53^{cm}$. $2\rho_2 = \cdot 40^{cm}$. $l = 6^{cm}$. $\theta = 180°$.]

Time.	Load.	Deflection.	Time.	Load.	Deflection.
h. m.	*kg.*	*cm.*	*h. m.*	*kg.*	*cm.*
3 21	0	23·6	3 47	10	24·1
23	0	23·7	50	10	24·0
25	4	24·1	51	15	24·0
30	4	24·2	55	15	24·2
31	0	24·0	56	20	24·3
35	0	24·4	60	20	24·1
36	10	25·5	62	0	24·3
40	10	24·2	63	20	24·5
41	0	24·3	67	20	24·3
45	0	24·8	68	21	Breaks.

These results do not certainly indicate any electrical effect of the applied stress at all. They narrow down its possible value to about 1 per cent, thus corroborating the results at 100°.

63. *Results of twisting.*—After making these experiments, the general character of which is negative, but not conclusively so, I made a variety of similar attempts to obtain an electric effect of twisting, but I arrived at no definite results, although I carried the experiments forward to the point of rupture. I omit the data.

64. *Differential apparatus.*—Having these results in hand it appeared probable that the work could be carried to a greater pitch of nicety by comparing strained and unstrained glass simultaneously.

The apparatus with which most of my definite experiments were made are shown in Figs. 10 and 11, and are differential in kind. The resistances across equal parts of the walls of two nearly identical glass tubes, respectively stressed and unstressed, are compared. These tubes are shown at *abcF* and *ekhf*. The ends proper are bent hook-shaped, and those of the glass tube to be operated on, fastened by aid of screws and cement, between slabs of wood *A* and *B*. *A* is fixed; *B* provided with a hook, *P*, from which a scale pan may be hung, or with a lever arrangement for twisting. In the experiments made the load was gradually increased as far as 20 kg., but the tubes were strong enough (theoretically) to sustain about three times this weight. The remainder of the figure shows the devices for heating and for passing the currents. Fig. 10 is adapted for high boiling points (aniline, etc.), Fig. 11 for steam. An apparatus similar to Fig. 10 was used for mercury. In Fig. 10, *G* is the ebullition liquid, heated by a Gibbs's ring burner *RR*

Digitized by Google

surrounding the wide glass tube *dd*. A narrower glass tube *gg*, closed below with a perforated cork through which pass the experimental tubes *abc* and *ekh*, is partially filled with sodium amalgam. This is practically one terminal of the battery, the wires connecting at *p*. The other terminal, after passing through the respective coils of a differen-

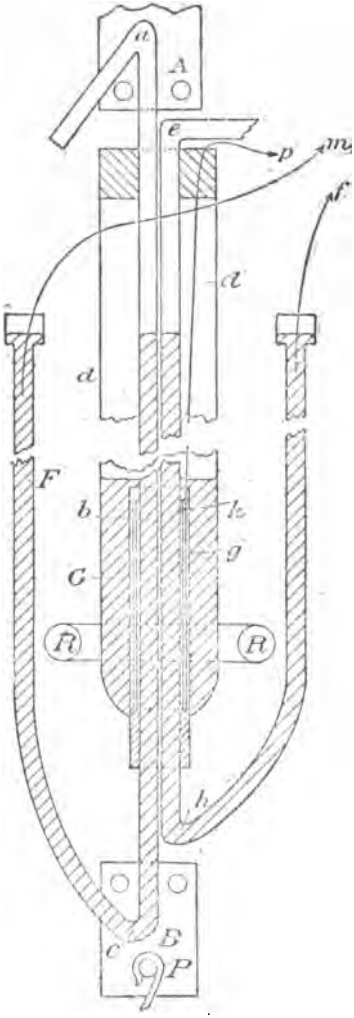


FIG. 10.—Apparatus for 200°.

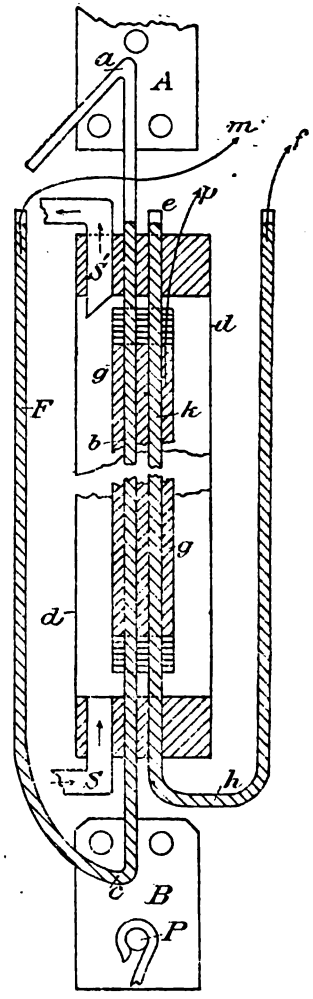


FIG. 11.—Appparatus for 100°.

tial galvanometer, connects at *m* and *f* with the sodium amalgam contained in the experimental tubes *abc* and *ekh*.

The notation in Fig. 11 is the same as that in Fig. 10. The two forms of apparatus are essentially identical, except that in Fig. 11 it is expedient to pass steam through *dd*, the vapor entering at *S* and

Digitized by Google

leaving the apparatus at *S'*. For reasons stated below, § 67, it is desirable that the menisci of the amalgam contained in *abcF* and *ekhf*, Fig. 10, be visible above the level of the upper cork of the tube *dd*. The amalgam in *gg*, Fig. 10, should be submerged below the level of *G*. Inasmuch as sodium amalgam is necessary only at the anode, ordinary mercury may be used at cathodal parts, and these may therefore be exposed to hot air or steam without annoyances. To summarize: Current arriving at *m* and *f* passes into the sodium amalgam core of the tubes *abc* and *ekh*, thence across the walls of the hot parts of these tubes into the mercury surrounding them, and finally via *p* back to the battery. Regarding other apparatus, cf. § 69.

65. *Results for torsion.*—I commenced work with torsion experiments of which I may indicate something here. A battery of 10 Grove cells was used and the apaline at *G*, Fig. 10, kept both below and at the temperature of ebullition. The deflection of each coil alone being 16·4^{cm}, it was found that the differential action (nearly zero) could not be modified by twisting more than 0·02^{cm}. Hence the specific electrical effect of twisting can not be greater than about 0·1 per cent. The resistances encountered in these cases were about 200,000 ohms. Profiting by this preliminary experience, however, I was ultimately able to detect and measure the effect of torsion on electrolytic conductivity, using a different and more sensitive method to be indicated below, § 69.

66. *Character of traction effects.*—In case of traction, the data decisively indicated an increase of conductivity proportional to the pull. But this result is necessarily complex in kind, and must be carefully scrutinized before its true signification can be stated. I will therefore give my experiments in chronological order, the first series being made at 185° (aniline), the second at 100° (steam), the third series finally at 360° (mercury).

One remark may be made at the outset: Inasmuch as the electrical effect of traction is persistent with the traction, and is an *increment* of conductivity, it can not be due to temperature. For the extension of an elastic solid like glass[1] produces temporary cooling, § 70.

67. *Results for traction.*—The resistance across the walls of the experimental tube at 190° was about 100,000 ohms. In case of intense ebullition, the temperature is not fully constant. It is therefore desirable to use the apparatus, Fig. 10, just below the boiling point of aniline, and to bring the plane of the ring-burner slightly below the plane of the ebullition liquid *G*. Parts of the apparatus which are not to be heated are screened with asbestos. In this way a nearly stationary distribution of temperature is reached.

Under these circumstances, when a weight of 18 kg. is alternately placed on the scale-pan and removed from it by mechanism, thus subjecting the tube to periodic pulls of the force given, a definite and persistent oscillation of the galvanometer needle ensues synchronously

[1] Cf. Sir William Thomson's Collected Papers, vol I, p. 308.

Digitized by Google

with the period of stress. The amount of this oscillation was found to be equivalent to a resistance-decrement of 1,500 ohms for the stressed tube. In other words, the effect of the pull of 18 kg. is a diminution of the resistance of the stressed tube amounting to about 1·4 per cent. These experiments were repeated many times with practically the same results; e. g.:

P = 2 kg., resistance reduced ·4 per cent
P = 15 kg., resistance reduced 1.2 per cent
P = 20 kg., resistance reduced 1·4 per cent

data in which the oscillation of the needle was made the basis of comparison. They betray a somewhat wide margin of error, because glass at 190° is exceedingly sensitive even to trifling changes of temperature. Nevertheless, the data are sufficient for the present purposes, and work of a more precise character with high-temperature vapor-baths seemed to me to be superfluous. By using a more sensitive galvanometer such measurements can be repeated at 100° with facility and much greater precision.

68. *Discussion of these results.*—The result obtained is clearly a superimposed effect, being due in part to the elastic change of dimensions during stretching, and in part to the direct action of stress in promoting molecular break-up. It is therefore necessary to estimate the value of the former influence.

The radii of the tube being $\rho_1 = \cdot 26^{cm}$ and $\rho_2 = \cdot 19^{cm}$, the section is about $q = \cdot 1^{cm^2}$. Supposing the tenacity of glass to be $6 \cdot 5 \times 10^8$ dynes per square centimeter, this tube should bear 65 kg. Tubes are rarely free from imperfections, such as result from insufficient annealing, and it is moreover difficult to apply traction in an experiment like the present without some flexural or other strain across the section (tendency to be crushed between the slabs AB at the supports, for instance). Hence, I found it practically difficult to strain these tubes with more than a pull of about 25 kg. without producing rupture. But from all this it appears clearly that the longitudinal extension produced by 18 kg. is much *below* the maximum for the given dimensions and mean strength of tube.

If the tenacity of glass be $6 \cdot 5 \times 10^8$ and Young's modulus $5 \cdot 5 \times 10^{11}$, the values given by J. D. Everett,[1] then the maximum longitudinal extension is ·0012. Again, since Poisson's ratio for glass is nearly $\frac{1}{4}$, it follows that the corresponding radial contraction is about ·0003.

Finally, the resistance R of a hollow cylinder, of length l, radii ρ_1 and ρ_2, and specific resistance s, to conduction across the walls of the tube is (M being the modulus of Brigg's logarithms):

$$R = \frac{1}{2\pi M} \frac{s}{l} \log \rho_1/\rho_2 = \cdot 3665 \frac{s}{l} \log \rho_1/\rho_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

To evaluate the resistance effect of elastic change of dimensions, R is

[1] Everett: Units and Phys. Constants, p. 56. These data are reduced from Rankine's "Rules and Tables," p. 395.

Digitized by Google

to be regarded as a function of l, ρ_1 and ρ_2. In view of the symmetrical occurrence of the last two variables, and if the simplifying relation $4\delta\rho_1/\rho_1=4\delta\rho_2/\rho_2=\delta l/l$, nearly, it follows that $\delta R'/R=(dR'/dl)\delta l/R+(dR'/d\rho_1)\delta\rho_1/R+(dR'/d\rho_2)\delta\rho_2/R=-\delta l/l$, where the accent has reference to elastic change.

Nevertheless radial contraction enters in case of an apparatus of the form Fig. 10, in which decrease of bore during traction lengthens the column of mercury contained. If λ be the length of this column before stretching, its length during stretching is $\lambda(1+2\delta\rho_1/\rho_1)=\lambda(1+(1/2)\delta l/l)$. Hence, in consequence of elongation of the mercury column, $\delta R''/R=-(\lambda/2l)\delta l/l$, nearly, where l is the length of the hot part of the column. Hence, the elastic discrepancy is

$$(\delta R'+\delta R'')/R=-(1+\lambda/2l)\delta l/l \quad \ldots\ldots\ldots\ldots\ldots (2)$$

In none of my apparatus did λ exceed $2{\cdot}5l$. Moreover, λ is always one shank of a U-tube. Therefore ·003 may be assumed as a decidedly superior limit of the numeric of equation (2).

Hence, in an extremely unfavorable case, the resistance effect due to elastic change of dimension (—·30 per cent) is only about one-fifth of the observed effect of traction (—1·4 per cent) produced by a pull much below the tenacity of glass, the said pull (18 kg.) being certainly not more than one-half the maximum load. These effects are very different, and it follows that the decrement actually observed is principally due to *decreased molecular stability* superinduced by stress. In equation (1), s is therefore the variable which chiefly responds to the action of stress.[1]

To obviate the troublesome occurrence of $\delta R''/R$, the column of mercury in most of my experiments was made so long as to extend far *above* the zone of conduction of the stretched glass tube (see Fig. 10). In the apparatus for steam (Fig. 11) the menisci of the column are advantageously raised quite above the cork. In such a case $\delta R''/R=0$, and the elastic discrepancy is simply $-\delta l/l$.

In one respect this reasoning is deficient. It does not take into account the changes of elastic behavior of glass due to the heating to 190°. Tabulated constants for this large interval are not available.[2] Hence special cathetometric measurements must be made. At 190° this is difficult, and for these and the other reasons given above (§ 67), it is expedient to refer to the complete set of measurements at 100°. (§ 69.)

[1] Put $\rho_1=\rho+e$ and $\rho_2=\rho-e$; $\therefore\ \rho_1/\rho_2=1+2e/\rho$ nearly. Then

$$\delta R'/R=\frac{dR}{dl}\frac{\delta l}{R}+\frac{dR}{de}\frac{\delta e}{R}=-\frac{\delta l}{l}-M\frac{\delta e/e}{\left(1+\frac{\rho}{2e}\right)\log\frac{\rho_1}{\rho_2}} \quad \ldots\ldots\ldots (2)$$

Here ρ, the mean radius, is supposed to remain constant, and the effect of traction is therefore an increment of length δl and a decrement of the mean thickness, $2e$, of the walls of the tube. Now, the value of $(dR'/de)\,\delta e\ R$ is relatively very small. Hence, $\delta e\ e=\delta 2e/2e$, and the radial contraction may be regarded identical. Then the value of $\delta R'\ R$ in equation (2) is

$$-\delta R'/R=+{\cdot}0012+\frac{{\cdot}0003\times{\cdot}434}{(1+3)\log 1{\cdot}4}={\cdot}0014$$

Hence the *superior limit* of the resistance effect due to elastic change of dimensions, $\delta R'/R=-.14$ %, not differing materially from the above.

[2] Kohlrausch and F. E. Loomis (Am. Jour. Sci. II, vol. 1, p. 350, 1870), give low-temperature data for metals.

Digitized by Google

69. *Traction at* 100°.—At 100° the results can be made more accurate than the above chiefly for two reasons: In the first place, the temperature is easily obtained absolutely constant; in the second, elastic changes of dimensions can be directly measured with facility. In Table 40 I have given the results obtained with the apparatus (Fig. 11.) The method of measuring these large resistances (glass at 100°) is necessarily chosen more delicate than above. I used a high resistance Thomson galvanometer, read off by Hallock's short-range telescope, and adjusted for differential work. The needle being practically ballistic in kind, the maximum deflections (swing) obtainable by alternately adding and removing the loads P were used for comparison (method of multiplication.) I then determined the amount of oscillation produced by inserting known resistances into one or the other coil of the differential galvanometer. Knowing the resistance of each tube (mean values) from special and preliminary measurements, I was able to deduce the percentage variation of the resistances of glass across the lines of stress. Table 40 contains four series of these experiments; i. e., two sets of results for each pair of tubes. R, the observed electrical resistance per tube, was found to be about 7,500,000 ohms per tube, of which the external and internal diameters were $2\rho_1 = \cdot 53^{cm}$ $2\rho_2 = \cdot 38^{cm}$, respectively. The table gives the oscillations for the divers loads P; the corresponding absolute decrement δR of R, and the relative value of this decrement in terms of R.

The amount of variation here given for glass is somewhat smaller than was found at 200° above. In the last case, however, the data are less accurate, and definite statements can not be made. In Table 40 the values for the second apparatus are smaller than for the first, a circumstance obviously depending on the tubes chosen, but which I will also leave without further comment.

TABLE 40.—*Resistance of stretched glass at 100°.*

Tubes.	P	Maximum oscillation.	δR	$10^3 \times \delta R/R$.	Method.
	kg.	*cm.*	*Ohms.*		
I and II	6	1·05	—21000	—2·8	Differential galvanometer.
	10	1·63	—33000	—4·4	
	15	2·20	—44000	—5·8	
	19	2·90	—58000	—7·7	
I and II	6	·87	—17000	—2·2	
	10	1·50	—29000	—3·8	
	15	2·17	—42000	—5·4	
	19	2·91	—56000	—7·3	
III and IV	6	·29	— 6000	— ·9	
	10	·74	—15000	—2·2	
	15	1·05	—21000	—3·1	
III and IV	6	·33	— 7000	—1·0	
	10	·76	—15000	—2·3	
	15	1·11	—22000	—3·3	
IV	5	·56	.....	—1·2	Bridge.
	10	1·33	.....	—2·8	

Digitized by Google

This table proves conclusively that, within the given limits of variation, the resistance decrement experienced by glass is proportional to the applied stress. For the given conditions ($2\rho_1 = \cdot 53^{cm} 2\rho_2 = \cdot 40^{cm}$) it is as high as $380/10^6$ per kilo stress, and is not below $210/10^6$ per kilo stress. Since the section $q = \cdot 10^{cm^2}$ nearly, it follows that the mean relative variation of resistance due to stretching is about $30/10^9$ per gram load, per square centimeter of section. Mr. H. Tomlinson,* who investigated the effect of stretching metals, finds that for steel, iron, and brass the total variations are only about $\frac{1}{13}$ as large as this, and of the opposite sign. Cf. §74.

70. *Further results at 100°.*—When the temperature is sufficiently constant, for instance, in the case of a steam bath, experiments may be made with a single tube. Let a bridge adjustment be so arranged that $a/b = r/R$ where r is a known rheostatic resistance and R the resistance of the tube, the current in the galvanometer being nearly zero. Then if $\delta r/r$ produce the same maximum oscillation of the needle as $\delta R/R$, it follows that $\delta r/r = \delta R/R$. An accurate chart or table of $\delta r/r$ considered as a function of the oscillation is therefore first to be constructed by aid of the rheostat. This being in hand, the value of $\delta R/R$ corresponding to any oscillation produced by alternately adding and removing the load on the tube, is given at once. This method may be made very accurate, and I was able to obtain not only traction effects, but torsion effects, as indicated by the following data. Here r is approximately 53,000 ohms, R approximately 5,900,000 ohms. In case of torsion, P denotes the load acting during the alternate twisting and untwisting.

TABLE 41.—*Resistance of stressed glass at 100°.*

Preliminary.		Traction.			Torsion.		
$10^3 \times \delta r\ r$	Oscillation.	P	Oscillation.	$10^3 \times \delta R/R$	P	Oscillation.	$10^3 \times \delta R/R$
	cm.	*kg.*	*cm.*		*kg.*	*cm.*	
·76	·35	5	·59	—1·3	0	·22	—·5
1·89	·89	10	1·27	—2·8	5	·29	—·6
3·77	1·63	16	1·86	—4·1	10	·28	—·6

The traction data $\delta R/R$ are numerically larger than in Table 40, and hence lend greater favor to the views just expressed. The torsion data $\delta R/R$ are of the same sign as the traction data. In other words torsion decreases the electrolytic resistance. They are of smaller magnitude than traction data and are independent of the load which the tube sustains, so far as I could follow them.

*H. Tomlinson: Proc. Roy. Soc., vol. 25, 1876, p. 451; ibid., vol. 26, 1877, p. 401.

Digitized by Google

TABLE 42.—*Longitudinal extension of the tubes, Table 40.*

Temperature.	Load.	L	$\delta L/L$	
°C.	*kg.*	*cm.*	$10^{-6}\times$	
16°	2	77·53	0	
	6	77·53	0	
	10	77·54	130	
	15	77·55	260	
100°	2	77·58	0	Coefficient of expansion ·000008.
	6	77·58	0	
	10	77·60	260	
	15	77·60	260	
100°	2	77·57	0	
	19	77·59	260	
100°	2	77·57	0	
	19	77·60	390	

71. *Dimensional change due to torsion.*—To interpret the above data special measurements of extension are necessary. These are given in Table 42. They were made cathetometrically and are not intended to give more than a safe estimate of the elastic effect in question. The glass tube to be examined was surrounded conaxially by a second wide tube of glass, through which steam at 100° continually circulated. Measurements were also made at 16°. L is the length between fiducial marks.

Utilizing these values to obtain a superior limit of the elastic discrepancy in Table 40, it appears that $\delta l/l < \cdot0004$ and $\delta\rho/\rho < \cdot0001$, these data being the largest obtained for the largest load, 18 kg. Hence by equation (2), $-\delta R'/R < 2\cdot5 \times \cdot0004 = \cdot0010$. In other words the elastic discrepancy is numerically much less than ·1 per cent of R, whereas the corresponding mean value for the traction effect in Table 40 (apparatus with tubes I and II, low menisci) is ·75 per cent. Again for raised menisci (Tables 40 and 41, tubes III and IV), $-\delta/R'/R = \delta l/l = \cdot0004$. In this case the corresponding mean value of the traction effect is numerically greater than ·50 per cent. In both instances it may be safely inferred that error introduced by elastic change of dimensions is at most about 1/10 of the decrement of resistance actually observed as the effect of stretching.

72. *Effect of temperature.*—I will make a final consideration here, relative to temperature. The thermal effect of traction is negative; its influence on R must therefore be a resistance increment, i. e., opposite in sign to the effect observed. Nevertheless, it is desirable to obtain some estimate of its value, which will probably be found too small for direct measurement. Since $P=20$ kg. and $\delta L/L < .0004^{cm}$, the total energy *elastically* potentialized per linear centimeter during stretching is $P\delta L/L < 10000$ ergs. Hence, even if all this energy were converted into heat, the increase of temperature resulting in case of the given

Digitized by Google

tubes (section $\cdot 10^{cm^2}$, density <3, sp. heat $<\cdot 2$) would be about $10^4/240\times 10^4$; *i. e.*, less than $\cdot 005°$. This datum is too small to produce serious error even in consideration of the phenomenal sensitiveness of hot glass to temperature variations. Estimating that the resistance of glass decreases several per cent (5 to 20) per degree between 100° and 200°, the thermal discrepancy can not be greater, numerically, than the elastic discrepancy.

73. *Traction at 360°.*—I have now to communicate the data obtained at 360°. This case possesses some points of special interest, because the differential apparatus is itself a battery, the action of which enters in a complex manner. The electrolytes here are the hot glass tubes containing amalgam and surrounded by mercury. The actual apparatus was a simplified form of Fig. 10. Fig. 12 presents a clearer diagram of parts, in which *a* and *b* are the hot glass tubes in question, *E*

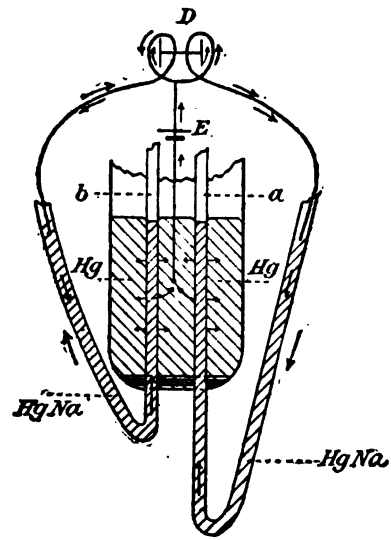


FIG. 12.—Apparatus for 360°.

the battery, and *D* the differential galvanometer. The electrical currents due to *E* are indicated by the *inside* arrows; but these currents are considerably reenforced by the action of the element sodium amalgam/hot glass/mercury, as shown by the arrows crossing the tubes *a* and *b*. The electromotive force of this element is easily found by reversing the action of *E*. In an actual experiment I measured NaHg /hot glass/Hg=1·4 volts, a datum somewhat affected by polarization and depending for its value on the strength of the amalgam and the purity of the mercury.

Besides this large electromotive force there is another of smaller value, due to the fact that the tubes *a* and *b*, with appurtenances, represent two elements switched against each other. The currents are indicated

Digitized by Google

by the *outside* arrows in the diagram, and they are necessarily so circumstanced as not to flow through the galvanometer G differentially. Their occurrence is therefore a serious and annoying disturbance, such that measurements at 360° can not, without unreasonable painstaking, be made with the same accuracy as measurements at 100°. I measured the electromotive force in question as about ·2 volt, but it is necessarily variable, even as to sign, containing as it does the polarization inconstancy of both elements.

Since the resistance of glass near 360° is enormously low relative to its value at ordinary temperatures (in some practical cases the apparatus showed less than 1,000 ohms), the extraneous electromotive force E can be withdrawn altogether. The present measurements of the electrical effect of traction are therefore made with the NaHg/hot glass/Hg element in the apparatus, Fig. 12, notation being as above, $2\rho_1 = ·53^{cm}$, $2\rho_2 = 40^{cm}$. The small resistance at the boiling point is not available; owing to the formation of bubbles at the surface of contact between mercury and glass, the resistance is too variable even for approximate measurement. Hence I observed at a lower temperature, encountering somewhat larger resistances R.

Even under favorable conditions these data are only qualitatively satisfactory. They are important, however, because they indicate that at 300° the diminution of resistance due to traction is not larger in numeric value than at 100°; and, since this would be the case if the decrements δR observed were due to elastic change of dimensions, I have here in hand additional evidence against this assumption.

TABLE 43.—*Resistance of stretched glass at 360°.*

Apparatus.	P	Maximum oscillation.	R	δR	$10^3 \times \delta R / R$
	kg.	*cm.*	*Ohms.*	*Ohms.*	
I	6	·50	13000	−30	−2
	10	·50	.....	−30	−2
	15	·70	.....	−50	−4
	19	·70	.....	−50	−4
III	6	1·00	17000	−15	−1
	10	1·40	.....	−22	−1
	15	2·00	.....	−31	−2

The present experiments are attended with much annoyance. As the load increases, the tube is apt to break in such a way as to spill the hot mercury; and with all reasonable care several tubes are usually sacrificed before a full series of observations can be obtained.

SUMMARY.

74. The above paragraphs summarized prove that a solid electrolyte like glass is a better conductor of electricity (*i. e.* manifests smaller specific resistance) when in a state of strain (traction torsion) than

Digitized by Google

when free from strain. Inasmuch as the necessary concomitant of conduction in this case is molecular decomposition[1] and recombination, stress of the given kind must promote such decomposition. The rate at which molecular reconstruction occurs per unit of volume increases nearly proportionally to the intensity of stress; and it may in case of traction be carried as far as the limit of rupture of glass amounts to an increment of 1 per cent. In case of torsion the effect is not much larger than about $\frac{1}{10}$ of this, and the increased break-up due to torsion is therefore studied with greater difficulty. The influence of temperature in changing the value of the electrolytic effect of stress is not marked. So far as observed the same pull per unit section does not increase the conductivity of glass more at 350° than at 100°, if indeed it increases it as much.

Again the traction effect in case of electrolytic conduction, being a decrement of resistance, is of the opposite sign of the traction effect in cases of metallic conduction[2] (increment of resistance). The former is also of decidedly greater magnitude. If, therefore, conduction in metals is essentially the same phenomenon[3] as in electrolytes, then the soft metallic state must be singularly well adapted to promote molecular reconstruction. This fine adaptation of structure is destroyed by strains of dilatation, by heat, by alloying,[4] etc. In the data given, the electrical traction-coefficient and the electrical temperature-coefficient (resistance) are similar in sign and in relative magnitude, both in metals and in electrolytes. They are positive in metals and small; negative in electrolytes and large. This is additional evidence in favor of a volume effect discussed at some length elsewhere.

75. *Degree of molecular instability of glass.*—The chief result of the present paper is the emphasis thrown on the fact that, independently of the passage of current, such a solid as glass must be conceived as undergoing spontaneous molecular reconstruction at all temperatures; for, if the reconstruction in question were superinduced by the electric field, then the current passing would vary at a power higher than the first of electromotive force; whereas it may be taken for granted that currents of the intensity of those discussed above pass through glass in accordance with Ohm's law.[5] Recently J. J. Thomson,[6] among many results of his development of the Lagrangian function, investigated an expression for the number of times n, the electric field is discharged at any point, in case of conduction through either metals or electrolytes. If λ be the specific conductivity, K the specific inductive ca-

[1] It is best to avoid the term dissociation here. The term molecular reconstruction is used in preference.

[2] Mousson: Neue Schweizer. Zeitschr., vol. 15, 1855, p. 33; H. Tomlinson: Proc. Roy. Soc., vol. 25, 1876, p. 451; ibid, vol. 26, 1877, p. 401.

[3] J. J. Thomson: Applications of Dynamics to Physics and Chemistry, 1888, p. 296.

[4] Am. Jour. Sci., vol. 36, 1888, p. 427.

[5] Fitzgerald and Trouton (Rep. Br. Assoc., 1886, p. 312) show that electrolytes obey Ohm's law accurately.

[6] J. J. Thomson: op. cit., p. 299.

Digitized by Google

pacity of the medium, then $n=2\pi\beta\lambda/K$; where β is a coefficient the value of which is less than unity and depends on the relative time of destruction and existence of the electric field. Accepting provisional values for β and K, Thomson computes a table of values for the superior limit of n, in cases both of metals and of electrolytes. From this table it appears that n for mercury, for instance, is less than 8×10^{15}. Similar values for the limit of n in case of glass at the above temperatures of observation, 100°, 200°, 360°, may be deduced. In round number the specific resistances of glass at the temperatures stated were 10^8, 10^5, and 5×10^3 ohms, respectively. From this it follows nearly that for glass at 100°, $n=8\times10^7$; at 200°, $n=8\times10^9$; at 360°, $n=16\times10^{11}$. Thus it is fair to conclude that at temperatures quite as low as 100° the spontaneous chemical action, i. e. the continuous rearrangement of the molecules of glass, is a pronounced occurrence.

The given value of the frequency of discharge of field, n, may be further expressed in terms of the number of molecules m, which break up per unit of volume, per unit of time, when the number of molecules q per unit of surface, whose disintegration just discharges the field, and the mean distance x, over which they are urged by the field during the interval between break-up and recombination, are known. For $n=mx/q$; or $m=n\,(q/x)$. Here x is a very small quantity, not exceeding the centimeter numeric of the mean free path of the molecule of a gas; whereas q is a very large quantity. Hence m is larger than the given value of n, even if the above superior limits be 100 times the true value of n.

These approximate statistics are the nearest exact statement for the phenomenon of molecular break-up which I can adduce, but they suffice for the present purposes. They show that even when glass is practically an insulator the number of active molecules m considered absolutely is very large and that m need by no means be negligibly small even in comparison with the total number of molecules per unit of volume.

The above paragraphs prove that the rate at which molecular break-up takes place is appreciably greater when glass is under stress than when it is not. It is improbable that the system will instantaneously pass from one state of molecular equilibrium to another Hence, since even in case of very high resistance, such as that of glass at 100°, the number of unstable molecules per unit of volume must still be conceived to be very large, it follows that the species of molecular break-up in question may be looked upon as a fruitful cause of viscous deformation.

Digitized by Google

CHAPTER IX.

THE ENERGY POTENTIALIZED IN PERMANENT CHANGES OF MOLECULAR CONFIGURATION.

76. *Introductory.*—In the following work a soft annealed wire is stretched by a known weight falling from an initial position (strain minimum) to the lowest position compatible with the given adjustment (strain maximum). If the wire remains sufficiently soft throughout the experiment the recoil is nearly zero. Hence the energy expended in stretching is to this extent easily measurable; and, if also the heat evolved during stretching be measured, the difference between the work done on each centimeter of wire and the heat produced per centimeter of wire is the energy potentialized; i. e., the energy which permanently manifests itself as tensile strain. Using the nomenclature of Maxwell's theory of viscosity, the numerical datum thus obtained is an expression for the amount of change in the history of the typical molecular configuration, the dates being taken immediately before and immediately after the tensile stress is applied.

Now it is clear that the strain effect of a given amount of work done must depend on the dimensions of the material. Strain must be supposed variable with the extension produced in case of a given sectional area, as well as with the section of the stretched wire in case of a given extension. At the outset it is difficult even to conjecture in what respect these strains, though of a given class, may differ in essential details. There is, however, a more interesting phase of these experiments: the strain-effect of a given amount of work done on centimeters of wire will vary, cæteris paribus, with the material acted upon. From this point of view the prosecution of the present research promises to lead to results bearing directly on the nature (form and mutual relations) of the molecules sustaining strain.

77. *Apparatus.*—In Fig. 13 CC, $C'C'$, the weights ($P=30$ kg to 60 kg) by which stretching is to be done are supported on a suitable trap door, BB; and the fall of BB, when released, is guided by the upright slides $ss, s's'$, fixed in the firm base, G, of the apparatus. I took pains to adjust the soft wire ab to be acted on as nearly straight and free from initial tensile strain as possible. It was firmly fastened above to a heavy cross-timber of wood, DD, the lintel of a framework which in form and purpose closely resembled a gallows. The screw clamp at a in the vertically adjustable brass torsion-circle A, the axle of which passes snugly through DD, secures the upper end of the wire. The

Digitized by Google

lower end is lapped around the hook of the weight pan, *bnn*, then wound around the wire and soldered, care being taken to avoid such loops and kinks as might change form during stretching.

A thermo-couple, $a\beta a\delta$, originally of platinum/platinum-iridium, with its junction β tied on with silk thread on the upper half of the wire *ab*,

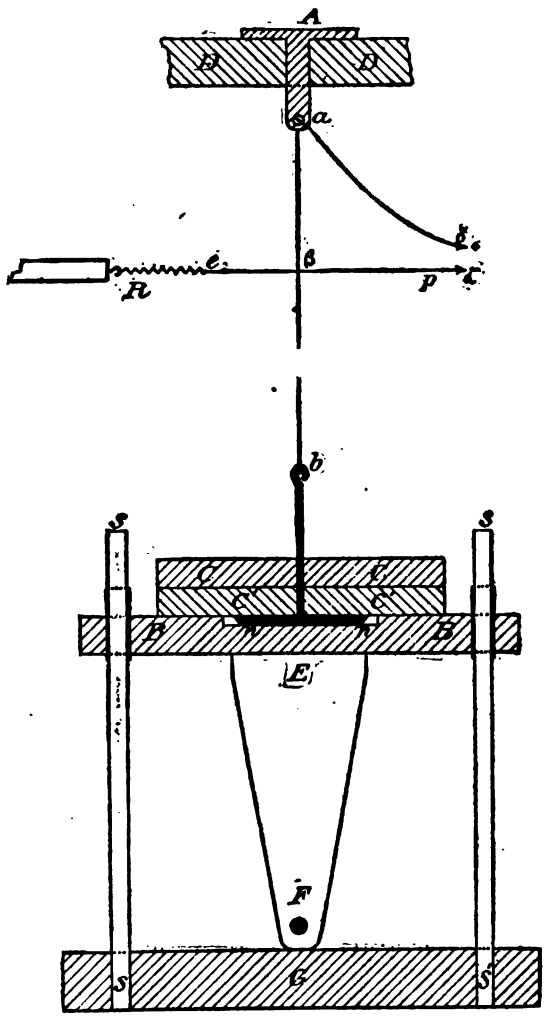


FIG. 13.—Apparatus for measuring the thermal effect of stretching.

enabled me to measure the change of temperature due to stretching. In later experiments more reliable devices were adopted; cf. § 80. Changes of length were measured with Grunow's cathetometer, two fiducial marks having been painted on the wire *ab* about 70^{cm} apart. At a given signal the catch-board *EF* of the trap door *BB* was jerked

Digitized by Google

way, by aid of a rope tied at F and manipulated by an assistant.[1] Simultaneously with the stretching I read off the temperature-increment in terms of the excursion of the needle of a sensitive mirror galvanometer, and as soon as this was taken I made the final length measurement with the cathetometer. From these both δL and δl, i. e., the length-increment of the whole wire and of the part between the ducial marks, respectively, were derived.

δL varied between 8^{cm} and 20^{cm}, δl between 6^{cm} and 11^{cm}, L being bout 120^{cm}.

78. *Results.*—In Table 44 I have systematized the results of the easurements. Here ρ_s and ρ_h denote the radii of the wire before and ter straining and are computed from gravimetric measurements. P the stretching force; $\delta l/l$, the longitudinal extension produced and easured between fiducial marks on the wire with the cathetometer. $=P\delta L/L=P\delta l/l$ is the work done on centimeter of length; t, the obrved increment of the temperature of the wire resulting. Finally, $=E_t/E$ indicates the part of the applied work which is converted into at, the remainder $(E - E_t)/E$ being potentialized. The table conins both $P\delta L/L$ and $P\delta l/l$, the latter being usually greater in conquence of errors of experiment which need not here be considered.

The heat corresponding to $t°$ being $Amct$, where A is the mechanical uivalent of the water-gram-degree in ergs, m the mass of the wire r centimeter, and c its specific heat. I was obliged to take c from bles and also for want of data to disregard the variations of c during aining.

TABLE 44.—*Energy potentialized in tensile strains. First method.*

Metal.	$\frac{2\rho_s}{2\rho_h}$	P	$\delta l/l$	$P\delta L/L$	$P\delta l,l$	t	$\dot{\tau}=E_t/E$
	cm.	*g.*	*(cm)*	*Megalergs.*	*Megalergs.*	*°C*	
Brass.....	·1662	60,000	·129	7·5	7·7	4·3	0·40
	·1546		·163	9·3	9·8	4·1	·30
			·151	9·0	9·1	3·9	·31
			·168	9·9	10·1	4·3	·31
			·153	9·1	9·2	6·0	·45
			·160	8·9	9·6	7·0	·52
Mean.....	.....	.....	·154	8·95	9·24	4·9	·38
Iron.....	·1362	50,000	·087	4·26	4·35	3·8	0·47
	·1310		·091	4·33	4·56	4·0	·47
			·084	4·17	4·22	4·3	·54
			·087	4·26	4·36	3·5	·43
Mean.....	.....	.....	·0875	4·25	4·37	3·9	·48
Copper...	·1630	40,000	·147	5·58	5·88	6·0	0·77
	·1514		·148	5·51	5·92	5·1	·65
			breaks	.....	.....	5·5	.....
			·153	5·90	6·12	5·3	·65
Mean.....	.....	.....	·149	5·66	5·98	5.5	·69

[1] Ernest L. Howard had the goodness to give me much efficient service during the course of the t experiments.

Digitized by Google

In Table 45 I have given the densities of the metals, strained and unstrained, Δ_s, Δ_h, and Δ_{hs}, referring to wires which are soft, strained hard, and softened after straining, respectively. Brass shows a slight decrease of volume after straining; but this result, like that of iron, is doubtless obscured by differences in the composition, hardness, etc., of parts of the annealed wire. Annealing the stretched iron wire scarcely shows any volume effect. In case of copper the effect of stretching is a definite increase of volume of a few tenths per cent. Small as this datum is, it is well to bear in mind that a like expansion of the wire produced by heat, calls for an increase of temperature of 30° or 40°. Elsewhere I have shown that it is scarcely safe to draw conclusions of this kind unless data are in hand in great numbers.

TABLE 45.—*Variation of density of stretched wire.*

Metal.	No.	Δ_s	Δ_h	Δ_{hs}
Brass.....	I	8·419	8·420	.....
Brass.....	II	8·411	8·419	.....
Iron.....	I	7·702	7·683	7·686
Iron.....	II	7·676	7·681	7·681
Copper ...	I	8·881	8·865	.....
Copper ...	II	8·879	8·867	.....

79. *Discussion of errors.*—A few words on the errors involved are essential. Comparison of the values of $P\delta L/L$ and $P\delta l/l$ shows that the work lost upon kinks and flaws, together with that spent upon the framework, is not seriously large so far as the present purposes are concerned. This is also true of the energy elastically potentialized, as may be found by direct tests. The satisfactory measurement of the thermal datum t, however, is much more difficult. Apparently the graduation of the thermocouple is simple, for it is merely necessary to make preliminary observation of the throw of the needle of a ballistic galvanometer produced by given increments of temperature. The use of such graduation is, however, only permissible if the temperature of the wire remains constant during the period of oscillation of the needle. These conditions are never rigorously given; whereas even in case of jacketed wires it is a question whether they are sufficiently given. The temperature of the wire increases very rapidly to a maximum, and then decreases by radiation, etc., reaching the original thermal value in a few minutes. Again the cooling effect of the metallic wires of the thermocouple can not easily be allowed for, neither can it be considered negligible even in case of filamentary wires. Finally the error of heterogeneity is of serious consequence; for the thermoelectric measurement is virtually a thermal exploration of the metal lying very near the point-junction. Hence since the wire near such a point may be imperfect by reason of flaws or composition, so that more or less work is done here than at other parts of the wire, it follows that the temperature

Digitized by Google

thermoelectrically obtained is not a mean datum for the wire taken as a whole.

Unfortunately the combined effect of the errors stated will usually be the cause of too small a value of t. Some assurance of the approximate truth of the results in Table 1 may, however, be obtained by observing that the experiments made are to some extent differential in kind. For instance, cœteris paribus, for an expenditure of only two-thirds the work applied to the brass wire, about the same heat is evolved in the copper and the brass. Sections and thermo-couple are here the same and similarly adjusted.

80. *Successive stretching.*—The importance of the thermal datum is such, however, that special corroborative measurements are essential. To obtain these, the above method was modified in such a way that the wire was stretched successively in equal amounts. One end of it was fixed and the other fastened on the circumference of an iron drum of small radius, $\rho = 0{\cdot}9^{cm}$. By revolving the latter the wire is stretched and the friction of the axle sufficient to keep it so. I chose successive angles of revolution, π, by which extensions $\delta L/L = {\cdot}054$ each were easily produced and could usually be repeated 4 or 5 times.

These accumulating strains are numbered in Table 46, in the first and second parts of which the data δt are obtained by a $Pt/Pt\text{-}Ir$ thermocouple with wires $0{\cdot}05^{cm}$ in diameter; in the third part by a filamentary iron / brass thermocouple (wires $0{\cdot}02^{cm}$ in diam.). Moreover in part I the junctions are fastened by binding them down upon the metal to be stretched by platinum wire. In parts II and III the junctions are bound down with silk, as in Table 44. In part IV the couple is of the kind used in constructing Table 47 below. The data of Tables 44 and 46 when referred to the same value of $\delta L/L$ agree fairly well. Some difference in favor of the silk fastening is apparent. Again δt increases in proportion as the wire is more nearly stretched to the point of breaking. This is in part due to the fact that as the wire hardens more work must be done to stretch it. When the wire breaks (strain V) the resilience is usually sufficient to increase δt appreciably in consequence of the energy elastically potentialized. Finally it is easily seen that, although the mean values of δt in case of the divers metals are not very different, this is not true for the amount of work done in stretching. P varies widely, being less in copper than in brass and less in initial than in final strains.

Digitized by Google

TABLE 46.—*Successive stretching.*

[$\delta L/L = 0{\cdot}054$ per pull.]

Metal.	Strain.	I.		II.		III.		IV.
		δt	δt	δt	δt	δt	δt	δt
Brass.....	I	.....	0·8	0·6	1·6	1·3	1·0	2·0
	II	1·1	1·0	1·4	2·0	1·6	2·2	2·5
	III	1·3	1·2	1·3	1·9	1·7	2·2	3·5
	IV.....	2·0	1·2	1·6	2·4	2·1	2·1	3·9
	V.....	.....	1·2	.....	2·6	3·0	3·2	.....
Iron	I	2·2	2·3					
	II	2·2	2·5					
	III	.....	2·9					
	IV.....	.....	2·8					
Copper ...	I	0·7	.....	.....	.....	.....	.....	.....
	II	1·7	.....	.....	.....	.....	.....	2·0
	III	2·0	.....	.....	.....	.....	.....	2·5
	IV	1·8	.....	.....	.....	.....	.....	4·0

81. *Results of improved methods.*—The errors discussed in § 79 induced me to repeat the work with a thorough change of method, so far as the thermal measurements are concerned. To obtain the data of Table 47, the thick wire *ab*, Fig. 13, was itself used as one of the elements of the thermocouple. The other element was a filamentary wire, $a\beta$, passing from a fixed point, *p*, in connection with the terminal of the galvanometer, once around the wire to be stretched (junction, β), and thence to an insulated spiral spring *R*, to keep it tense. At the point, β, where the thin wire lapped around the thick wire, both were carefully brightened and good electrical contact was further insured by stiffening the spring *R* as much as the thin wire permitted. The upper end *a* of the wire to be stretched placed in connection with the other terminal δ of the ballistic galvanometer completed the circuit. In this way the heat generated by stretching acts at once at the thermoelectric junction of the thick and the filamentary wire, while the latter may be chosen so thin as to produce only negligible cooling. Indeed, in virtue of friction the discrepancy is apt to be in the opposite direction.

In this arrangement,[1] a special error is introduced by the change of thermoelectric constants due to stretching, but this error, for the present purposes at least, is negligible in comparison with the thermoelectric powers copper/iron or brass/iron, being not greater than a few per cent.

The notation of Table 47 is the same as that in Table 44. E_p, the mean energy stored in the wire per centimeter of length, has been added.

[1] After making these experiments, I found that a similar method of thermoelectric measurement has recently been employed by Wassmuth (Wiener Sitzber., vol. 92 (2), 1888, p. 52). Wassmuth's purposes are distinct from mine.

Digitized by Google

TABLE 47.—*Energy potentialized in tensile strains.—Second method.*

Metal.	$2\rho_2$ / $2\rho_1$	P	$\delta l/l$	E	t	E_t/E	E_p
	cm.	*g.*	*(cm.)*	*Megalergs.*	*°C.*		*Megalergs.*
Brass	·166	60,000	·190	11·8	9·1	0·55	5·0
	·155		·191	11·5	9·0	·56	
			·182	10·9	8·8	·58	
Copper ...	·163	40,000	·153	6·12	6·8	0·81	1·3
	·151		·153	6·12	6·1	·72	
			·153	6·12	6·8	·81	
			·143	5·72	6·0	·76	
			·143	5·72	6·3	·80	
Iron	·136	50,000	·084	4·21	4·0	0·51	2·2
	·131		·086	4·28	3·9	·49	
			·089	4·47	4·3	·51	
Iron	·136	40,000	·032	1·26	0·8	0·36	0·9
			·031	1·23	0·5	·22	

A comparison of the results of Table 44 and Table 47 shows that the latter substantiates and emphasizes the results of the former. In Table 47, moreover, the measurements of the effects produced by stretching the same metal are in very much better accord. It is not improbable that the variations of E_t/E for the same metal in Table 2 may be due to actual differences of hardness or composition of the annealed wires.

In case of iron two values of P occur and the metal exhibits striking differences of behavior in the two experiments. It appears that more energy is potentialized during initial than during final stages of strain. For P=40 kg, the small value of t is only measurable as a superior limit. Moreover the extension is here so small that the error due to resilience may be 5 per cent.

82. *Summary.*—To summarize: It appears that as much as one-half of the work done in stretching up to the limit of rupture may be stored up permanently; that the amount of work thermally dissipated varies considerably with the metal acted upon, being very large for instance in the case of copper (75 per cent), smaller in case of brass (60 per cent) and of iron (50 per cent); that in case of the same given metal the work done is very largely potentialized during the incipient stages of strain and very largely dissipated during the final stages of strain. When stress of a given kind is applied to different metals, the total amount of energy which can be stored per unit of section, per unit of length up to the limits of rupture, may therefore be looked upon as a molecular constant of the metal. Table 44 shows that in case of a wire about .16^{cm} thick stretched nearly to the limits of rupture, at least 5 megalergs per centimeter will have been stored in case of brass and about 1 megalergs per centimeter in case of copper. In iron ·14^{cm} thick at least 2 megalergs per centimeter are potentialized under the same conditions.

Digitized by Google

Perusing the present chapter as a whole it will be seen that the experiments made are closely analogous to the usual mode of thermochemical measurement. The difference between the initial and the final energy of a system of two interacting liquids is the heat evolved during mixing. In solid metals this experiment can be made with a single substance. The reactions are such that energy is absorbed during straining; in other words, the difference between the final and the initial energy of the system of weight and wire is the heat evolved in stretching. It does not follow, however, that the increased intrinsic energy of the strained metal occurs in consequence of the formation of new molecules of greater intrinsic energy; for the added energy may be stored in modified systems of the original molecules. Nevertheless it is interesting to note that the diminished viscosity which usually results from permanent strain corresponds to an increment of the intrinsic energy. Viscous motion is therefore the result of the tendency of the increment of energy to dissipate, since the systems within which it is stored are unstable.

Digitized by Google

CHAPTER X.

THE CHEMICAL EQUILIBRIUM OF SOLIDS, IN ITS RELATION TO PRESSURE AND TO TEMPERATURE.

EARLIER RESEARCHES.

83. In a recent number of the American Journal[1] I communicated certain data on the effect of dilatational strain on the electric resistance of glass. These experiments, though decisive as to results, were somewhat complex in character; and from their important bearing on the chemical equilibrium of solids, I resolved to attack the subject from a new point of view. The present work is direct, and I hoped that results could thus be reached without necessitating auxiliary hypotheses or experiments. In this expectation I deceived myself: the insulating oil which transmits pressure to glass shows a pressure-coefficient usually much larger than the glass itself. Both must therefore be studied. Nevertheless the confirmation of my earlier results which the present paper gives is gratifying. I am thus able to carry the deductions one step further. Again, the behavior of liquid hydrocarbon insulators under pressure presents many points of special interest in relation to the formation and occurrence of ions.

As a result of the investigation of different oils, I have been able to increase the efficiency of my screw-compressor[2] in marked degree. By using a sticky *mineral* machine oil, thick enough to be almost opaquely fluorescent[3], not only does the screw of my apparatus run more easily, but leaks at high pressure are practically absent. Moreover, the gasket of marine glue is not in any measure dissolved (this is the case with sperm oil), and it therefore lasts indefinitely. Finally, the insulation of barrel and piezometer is now at least as high as 10,000 megohms and need not be less than 1,000 megohms. This is an important requisite in experiments like the present.

The special work on the effect of pressure on the electromotive force of the cell NaHg/glass/Hg has intrinsic interest apart from its subsidiary purpose as embodied in the present text. From experiments to be published in a bulletin of the U. S. Geological Survey, I infer that the secret of the relation of the Peltier contact to the Volta contact will probably manifest itself, if a suitable cell, suitably compressed, be carried through a large range of temperature quite into red heat.

---

[1] Am. Jour. Sci., vol. 37, 1889, pp. 339–351.

[2] Phil. Mag., 5th ser., vol. 30, 1890, p. 338.

[3] Possibly containing rubber.

Digitized by Google

gain another inference by comparing the present results with the of my last paper[1] on the effect of pressure on the thermal rela- of metallic and electrolytic conductivity.

nally, the present work is tributary to an extended series of exper- ts on the relation of melting point and pressure, as will appear in § 88. Thus it forms an essential part of the work suggested by Mr. Clarence King.

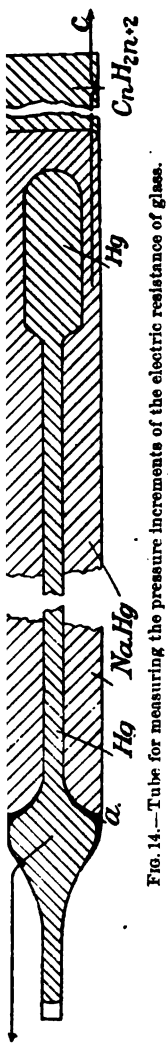


FIG. 14.—Tube for measuring the pressure increments of the electric resistance of glass.

APPARATUS.

84. *Compressor.*—Hydrostatic pressures as high as 1,500 atmospheres were applied. Having found that within the limits of the present paper nothing essentially novel was gained by excessively high values of pressure, I facilitated my work by ayoiding them as much as possible.

85. *Vapor baths.*—To obtain different constant temperatures, the tubes were exposed successively to vapors issuing from water (100°), turpentine (160°), naphthalene (215°), and diphenylamine (310°). A serviceable continuous vapor bath for this purpose is also described in the paper last cited. I need only add that the ends of the brazed copper bath are provided with screw stuffing-boxes of the ordinary kind, in which either asbestus packing or a hollow cylinder of cork may be forced home by the gland. Vapor baths must be removed hot. They then slide off the smooth steel piezometer easily, and without jarring the tube.

86. *Insulation.*—In the compressor the arrangement adopted is that of insulating the piezometer tube from the barrel and compression appurtenances. Inasmuch as in some of the experiments the resistances to be measured amount to several hundred megohms, the piezometer insulation must be perfect to at least several thousand megohms. How this was gradually accomplished will be explained in §§ 94 et seq. Gutta-percha covered wire and raised hard-rubber commutators are essential. Care must be taken to insulate the water-jackets which cool the of the piezometer, and to allow the efflux water to drop into a n discontinuously. The burners which heat the vapor bath must nsulated to prevent conduction through the flame, etc. At high eratures, where the resistance of the glass will have decreased al hundred to one, many of these precautions are superfluous. are always necessary when oils are examined.

[1] Am. Jour. Sci., vol. 40, 1890, pp. 219-223.

Digitized by Google

87. *The resistance tube.*—The original apparatus for measuring the resistance of compressed glass is shown in Figures 14 and 15, of which the latter is a diagram. Fig. consists essentially of two coaxial glass tubes, the larger completely surrounding the smaller. The diameter of the larger (thick-walled) tube is ·4 to ·5^{cm}; that of the inner (thin-walled) tube is ·2^{cm}. They are joined along the ring . Two separate compartments are thus formed, the inner of which is filled with pure mercury and the outer with sodium amalgam, to a sufficient length to completely envelop the inner tube. The end of the large tube contains hydrocarbon to protect the amalgam against moisture or air when the tube is not in use, and also to prevent saponification of sperm and to eliminate condensed air when the tube is in use. Mercury and the amalgam are to be introduced by aid of the air-pump, care being taken to expel all traces of air. The mercury of the inner compartment is in galvanic connection with the platinum wire *b*, which in its turn connects with the piezometer

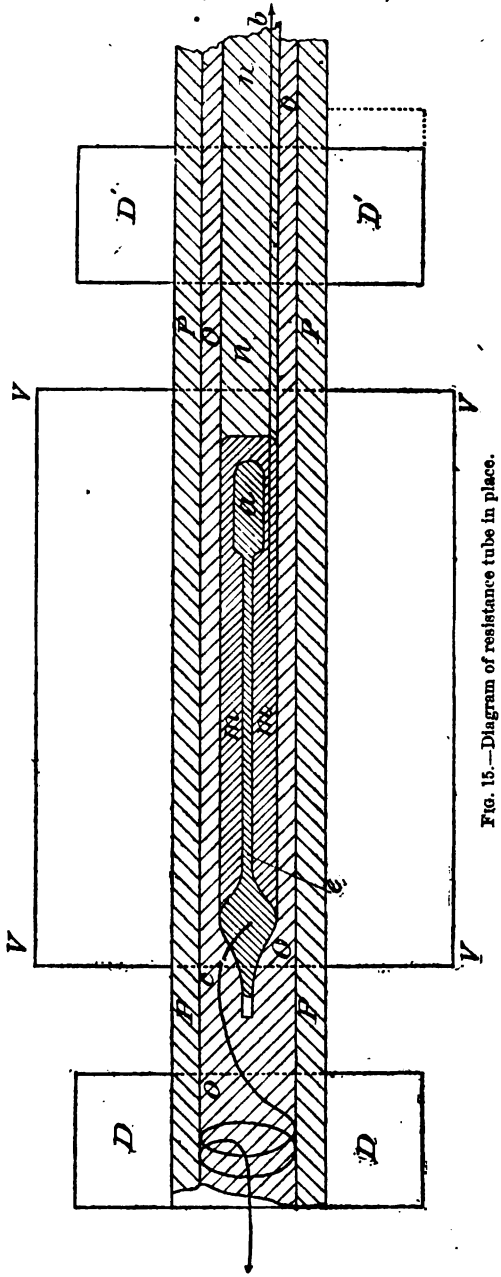


FIG. 15.—Diagram of resistance tube in place.

Hence *b* need not be insulated. The amalgam is connected by the terminal *c*, which is completely insulated from the piezometer by the *unknown length of cold-glass tube* surrounding the wire. To prevent the wire from being pulled out of place during the adjustments, *c* is bent in the inside of the insulator tube as shown in the figure. This

Digitized by Google

terminal is in galvanic connection with the barrel. It is seen that the tube is virtually a galvanic cell, NaHg/glass/Hg, and is reversible.

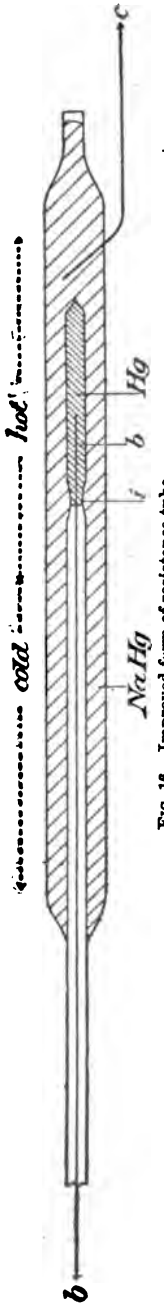


Fig. 16.—Improved form of resistance tube.

Under the influence of hydrostatic pressure the figure of the glass tube is symmetrically reduced in size. Hence, with regard to the conduction taking place across the walls of the *inner* tube, the resistance would be increased, in consequence of changes of dimensions, only by the amount in which the length of the inner tube is diminished. In other words, if $r = sl/2\pi RL$, where s, l, R, L denote respectively specific resistance, thickness, radius, and length of thin tube, then the dimensional effect of pressure is $\delta r = (s'l/2\pi RL) \times \delta L$ L, nearly. But all such values ($\delta L/L$ being less than .1 per cent per 1000 atm.) are negligible in comparison with the relatively large pressure coefficients actually obtained (cf. Tables 48 to 55,) and to be interpreted with reference to $s' - s$.

Fig. 15 (diagram) shows the resistance tube in place. PP is the tubular steel piezometer, surrounded by the vapor-bath V V, and the cold-water jackets D D and D′ D′, and filled with the oil O O, by which the pressure is transmitted. The inner compartment of the glass tube is at *a* (mercury), the outer compartment at *m m* (sodium amalgam), with petroleum at *n n*. The terminal wires are shown at *b* (cathode connecting with the piezometer) and at *c* (anode, insulated).

88. In the course of my work, however, I found it essential to connect *c* with the piezometer and to insulate *b;* for by thus reversing the tube there is no tendency of short-circuiting through oil and the *outer* tube. Indeed, so important is this adjustment, that I further modified the tube, Fig. 13, in the way indicated in Fig. 16.

Here the inner compartment is filled with mercury to only about 7^{cm} of the end. The remainder of the tube, containing hydrocarbon oil, runs completely through the piezometer into the barrel, with which the insulated platinum terminal connects. To keep the mercury in place, the inner tube is drawn down to a smaller diameter (see *i*, Fig. 3), into which the mercury meniscus projects. Air is excluded by boiling the mercury with the platinum wire in place. The latter amalgamates externally, but careful handling is none the less advisable. The outer tube, with its filling of sodium amalgam, not only envelops the inner mercury thread, but extends in both directions as far as the *cold* parts of the surrounding piezometer tube. Since *c* connects with this, no current will

Digitized by Google

pass through the film of *hot* oil and the outer glass tube. All currents between piezometer and barrel must therefore pass through the walls of the inner glass tube—a condition which is further insured by making NaHg/glass/Hg the acting electromotive force. I have purposely described these precautions at length; and their importance is obvious when it is remembered that the oil medium has a larger pressure coefficient than glass, and that the insulation of oil sometimes breaks down in marked degree with rise of temperature (§ 103). The effect of cold oil can be found preliminarily, when the whole apparatus is cold.

89. *Arrangement for testing insulation.*—I have finally to show the apparatus for testing the resistance and pressure coefficient of the liquid insulators at different temperatures. This is given in Fig. 17 (diagram), and consists essentially of a cylindrical steel rod *s s*, adjusted coaxially with the steel piezometer P P, containing the oil to be tested. Tubes of glass, *g g*, hold the rod *s s* in position. Owing to the fact that above 200° glass conducts better than most hydrocarbon oils, this insulating arrangement is not quite satisfactory; but by using thin-walled

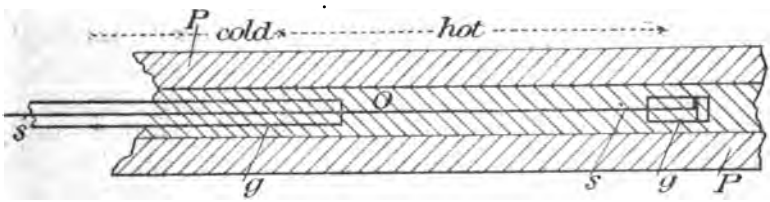


FIG. 17.—Arrangement for measuring the pressure increments of the electric resistance of liquid insulators.

glass tubes filled with the oil, the data so obtained are sufficient for the purposes of the present text, since the rate of breakdown with temperature is accentuated. It is seen that the measuring current passes from the piezometer P P, through the cylindrical layer of oil, into the rod *s s*, and thence to the battery. The diameters of steel core and piezometer tube being ·13 and ·63 centim. respectively, and the exposed part 9 centim. long, the specific resistance of the layer of oil is easily computed (§ 103).

90. *Digression.*—By filling the greater part of the closed end of the inner tube (Fig. 13 or Fig. 14) with the substance to be examined, and the open end as far as *e* with mercury, the tube is available for the study of melting point and pressure. In such a case the forward motion of the inner mercury meniscus due to pressure proportionately decreases the resistance of the arrangement by increasing the opposed surfaces of mercury and sodium amalgam. Increased delicacy is secured by enlarging the bulb at the end of the inner tube. At the solidifying point the sample usually undergoes a phenomenal reduction of volume, corresponding, therefore, to a similarly large reduction of resistance. This occurrence I propose to use as the criterion of solidifying point and of

Digitized by Google

melting point. The apparatus is available above 100° under any pressure up to several thousand atmospheres.

The criterion specified is also available when a fine platinum wire is stretched through contiguous coaxial columns of the substance and of mercury in a vertical piezometer.

91. *Resistance measurement.*—Resistances were first measured by a bridge method; but owing to the fact that electromotive forces are involved which may themselves vary with pressure, I lost faith in the safety of these methods and replaced them by simple circuit methods. The errors to be guarded against are primarily in the experiment itself. Again, the resistance tube (Figs. 14–16) is well adapted for simple circuit work, since the electromotive force NaHg/glass/Hg may exceed a volt, and the only pronounced resistance is in the cell. Only at 100° need auxiliary cells be inserted.

Throughout the work the low-pressure or fiducial resistance is measured *before* and *after* the high-pressure resistance. This safeguard is necessary. From three to five minutes were allowed for the elimination of thermal discrepancies. The fiducial resistance is to be measured under a pressure of 100 to 200 atmospheres, both to condense the air retained in the pump and to make the oil less compressible (§ 116). Not much care was taken in measuring the absolute resistances, since the inferences of this paper are to be drawn from the increments.

92. *Galvanometer.*—In the high-resistance experiments I used the Elliott square pattern of Thomson's high-resistance astatic galvanometer. The readings, however, were made by Poggendorff's method of telescope and scale. To adapt Thomson's concave-mirror adjustment to this purpose, I compensated the curvature by an ordinary "No. 36" concave spectacle glass fixed in front of the mirror, diffuse light being suitably screened off. Glass "No. 36" slightly undercompensates the mirror, leaving some magnification which is not undesirable. How far a weak telescope may be made to do the service of a more powerful instrument, by virtue of the concave mirror and a lens even weaker than No. 36, remains to be seen. With the above adjustment of lens and mirror, using a telescope magnifying somewhat over 20 diameters, and a scale somewhat further than 2 meters from the mirror, I obtained an image about 4·5 centim. long and sufficiently distinct for all practical purposes. Thus, if one volt act in one million megohms, the current produced would only just escape detection.

At 200° the galvanometer was suitably shunted.

93. *Other adjustments.*—Regarding other manipulations, the paper cited in § 84 will have to be consulted. Electromotive forces were measured by a zero method.

OBSERVATIONS.

94. *Tables explained.*—Table 48 contains data for the apparent change of the resistance of glass with pressure, when the liquid which transmits pressure is ordinary saponifiable sperm oil. Here θ denotes the

Digitized by Google

temperature of the vapor bath, approximately, and R the resistance of the uncompressed glass shell. $\delta R/R$ is the *increment* of resistance, R corresponding to the pressure increment δp, where the initial pressure is at least 50 atmospheres (§ 91). $k_r = \delta R/R . \delta p$ is the pressure coefficient. To save space, I have taken the mean of the two or three complete triplet observations for each δp given. The table contains six independent series of experiments, made at different times and often with different tubes. The adjustment, however, was in the main that of Fig. 15 reversed.

TABLE 48.—*Apparent effect of pressure (in atmospheres) on the resistance of glass, in an insulating medium of animal sperm oil.*

Series No. θ R Mean $k_r \times 10^6$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$	Series No. θ R Mean $k_r \times 10^6$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$
I.	82	470	174	III.	51	480	110
215°.	160	835	193	310°.	99	877	113
117×10^3	213	1180	181	—	165	1320	125
182.				116.			
I.	75	455	167	IV.	164	450	365
215°.	157	825	191	100°.	330	930	355
117×10^3	217	1160	188	—			
183.				360.			
I.	59	497	119	IV.	112	515	217
310°.	117	830	142	160°.	102	525	196
6×10^3	170	1175	145	—	111	610	185
137.				200.			
I.	61	470	130	VI.	420	605	685
310°.	116	845	136	100°.	420	650	640
6×10^3	158	1155	137	—			
134.				660.			
II.	67	390	171	VI.	127	655	194
215°.	135	750	180	160°.	136	644	211
122×10^3	195	1070	182	—	141	674	209
178.				203.			
II.	49	450	112	VI.	126	657	192
310°.	97	790	122	215°.	123	691	177
9×10^3	145	1120	127	—	127	688	184
121.				184.			
III.	85	516	163	VI.	97	689	143
215°.	165	1000	163	310°.	89	639	138
120×10^3	219	1405	156	10^4			
161.				140.			

95. *Remarks on the table.*—A graphic construction shows the character of these divers series to be identical, though the individual pressure coefficients show marked variation. The data of the third series are made in connection with the following data of Table 49, in which electromotive forces are measured before and after the resistance measurements. As a rule, the galvanometer needle does not reach its position

Digitized by Google

of equilibrium at once; the slow changes registered are probably due to gradually vanishing thermal discrepancies (§ 121).

96. *Electromotive force.*—Table 49 gives results for the effect of pressure on the electromotive force NaHg/glass/Hg. Here θ is the temperature of the vapor bath, and e the observed electromotive force, in volts, corresponding to the pressure δp, when the initial pressure is above 50 atmospheres (§ 94). $k_e = \delta e/e \,.\, \delta p$ is the pressure coefficient. Five minutes were allowed per observation. Special experiments showed that e decreases on cooling. The medium for transmitting pressure is again ordinary animal sperm oil. Earlier observations were discarded, and the results are condensed as far as possible.

TABLE 49.—*Apparent effect of pressure on the electromotive force of NaHg/glass/Hg.*

θ Mean $k_e \times 10^6$	δp	$e \times 10^4$	$10^6 \times k_e$	θ Mean $k_e \times 10^6$	δp	$e \times 10^4$	$10^6 k_e$
100°.	0	5180	—	†215°.	0	11182	—
230.	720	5950	210	10·9	488	11244	11·3
	0	4300	—		0	11210	—
	1080	5440	245		992	11332	11·0
	0	10872	—		0	11224	—
*215°.	533	10904	5·5		1378	11374	9·7
7·3.	0	10912	—		0	11214	—
	524	10950	6·7		550	11286	11·7
	0	10922	—	310°.	0	10658	—
	551	10908	7·7	5·1.	505	10672	2·5
	1010	10996	6·8		0	10666	—
	0	10924	—		480	10706	7·8
	535	10976	8·9				
	1011	11008	7·7				
	0	10924	—				
	542	10972	8·2				
	1033	11004	7·2				
	1441	11024	6·5				
	0	10912	—				
	540	10968	9·6				
	1027	11004	8·3				
	1436	11028	7·4				

* Before the resistance measurements.
† After the resistance measurements.

97. *Remarks on the table.*—To facilitate measurement, the greater number of experiments are made at 215°. Polarization was observed; and for this reason the measurement of temperature coefficients by removing and readjusting vapor baths was not tried. The increment of electromotive force is largest immediately after compression (temporary effect), and then decreases to the apparently constant values of the table. The converse holds for the decrement on removing pressure. At 100° no satisfactory results could be obtained (§ 118). At 310°, although the temporary effects were distinct, the permanent effects are not warranted.

Digitized by Google

98. *Pressure coefficient of sperm oil.*—Table 50 contains results, given on a plan identical with that of Table 48, for the case in which the glass tube (Fig. 14) was removed and the steel rod (Fig. 17) inserted. In this way the pressure coefficient of ordinary sperm oil was found. Table 50 also contains results for glass made after the work with oil.

These results are shown in Fig. 18, where little circles distinguish the observations for oil.

The pressure coefficient of sperm oil is therefore decidedly larger, and the specific resistance of this oil is usually smaller, than that of glass (cf. § 103, Tables 56 and 57); but the breakdown of resistance with rise of temperature is more marked in the latter case. Nevertheless the data of Table 50 cast grave doubt on the trustworthiness of the data of Table 48; and hence a search must be made for more highly insulating liquids. For obvious reasons I selected the hydrocarbon oils of the paraffin series.

99. *Pressure coefficient of gasoline.*—Table 51 contains data for the insulation and pressure coefficient of very volatile gasoline.

These results are shown in Fig. 19.

The resistance of gasoline is therefore enormous as compared with sperm oil, and above 100° more than 100 times that of glass. More-

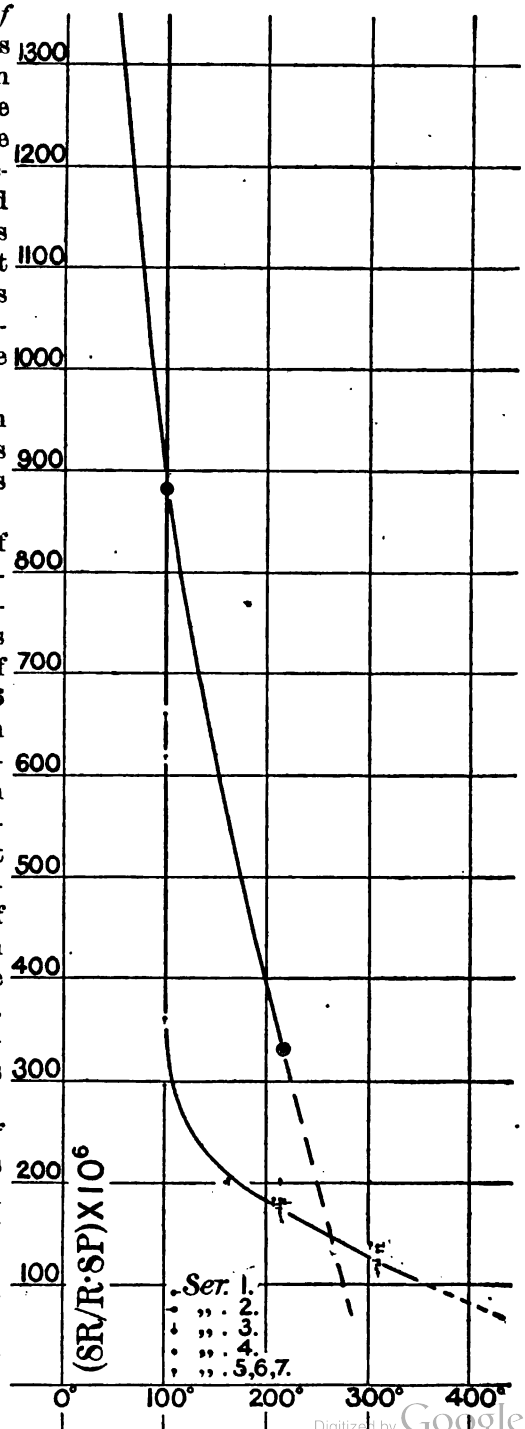


FIG. 18.—Pressure coefficient and temperature for sperm oil and for glass.

Digitized by Google

over the breakdown of the gasoline insulation with temperature is remarkably slow; but owing to the difficulty of keeping the apparatus free from leaks in the case of this very thin oil, I did not make experiments with the glass tube.

TABLE 50.—*The insulation and pressure coefficient of sperm oil.*

[$p_0 = 100$ atm. Pressure coefficient of glass.]

Series No. θ R Mean $10^6 \times k_r$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$	Series No. θ R Mean $10^6 \times k_r$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$
1.	3300	540	6200	Glass tube inserted.			
20°.	3500	573	6100				
$18 \times 10^6\omega$	8100	1240	6500	VII.	347	570	600
×5700.	6500	1140	5700	100°.	373	580	640
	2200	553	4000	$240 \times 10^6\omega$			
				620.			
1.	500	550	910				
100°.	550	610	890	VII.	90	570	157
$2 \times 10^6\omega$	990	1150	860	215°.	94	560	170
+880	460	550	840	$500 \times 10^3\omega$	186	1000	186
				171.			
1.	180	550	330				
215°.	200	600	330				
$300 \times 10^6\omega$	230	675	340				
+330.							

A feature of these results is the negative pressure coefficients found, which themselves decrease algebraically nearly proportionally to the temperature of the oil. At a given temperature the resistance is not constant, but decreases; and since the gasoline is discolored when removed from the press, the decrease of resistance is undoubtedly a solution phenomenon. Indeed, I suspect that negative coefficients are possibly to be associated with solution (§ 123).

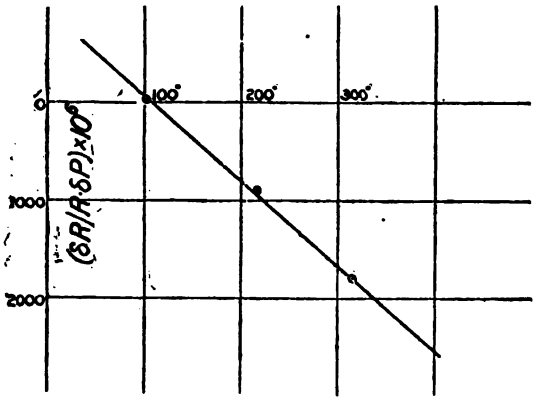


FIG. 10.—Pressure coefficient and temperature for gasoline.

100. *Pressure coefficient of petroleum.*—In Table 52 data are given for ordinary illuminating oil (petroleum). The glass tube still has the form of Fig. 14, reversed. Two sets of experiments were made.

TABLE 51.—*Behavior of gasoline under pressure.*

[Initial pressure, $p_0 = 200$ atm. Resistance at 20°, $2 \times 10^6 \omega$.]

Series No. θ R Mean $k_r \times 10^6$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$	Series No. θ R Mean $k_r \times 10^6$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$
2.	0	250	0	2.	—380	250	—1500
100°.				310°.	—550	300	—1800
$450 \times 10^6\omega$				$220 \times 10^6\omega$	—580	300	—1900
to				—1800.	—550	300	—1800
$130 \times 10^6\omega$					—590	300	—2000
± 0.							
2.							
215°	—330	250	—1300				
$220 \times 10^6\omega$	—290	280	—1050				
to	—200	280	— 710				
$150 \times 10^6\omega$	—140	220	— 640				
— 890.	—190	250	— 700				

TABLE 52.—*Insulation of pressure coefficient of petroleum.*

[Initial pressure, $p_0 = 50$ atm. Pressure coefficient of glass.]

Series No. θ R Mean $k_r \times 10^6$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$	Series No. θ R Mean $k_r \times 10^6$	$10^3 \times \delta R/R$	δp	$10^6 \times k_r$
3.	700	460	1530	Petroleum tested again. $p_0 = 200$ atm.			
20°.	700	480	1460	4.	560	370	1509
$370 \times 10^6\omega$				100°.	750	360	2100
+ 1500.				$740 \times 10^6\omega$			
3.	520	580	890	+ 1800.			
100°.	570	760	750	4.	115	310	380
$130 \times 10^6\omega$				215°.	193	305	640
+ 820.				$64 \times 10^6\omega$	166	300	553
3.	134	570	234	+ 560.	200	300	667
215°.	167	590	282	4.	—115	300	—383
$40 \times 10^6\omega$	177	580	306	310°.	—175	550	—320
+ 274.				$32 \times 10^6\omega$	—100	285	—360
3.	—285	550	—521	— 340.	—105	290	—360
310°.	—281	570	—492		—140	523	—270
$47 \times 10^6\omega$	—229	570	—404		—115	298	—383
to	—223	640	—349		—130	495	—265
$34 \times 10^6\omega$	—192	520	—369		—105	280	—380
— 430.							
Glass tube inserted.							
VIII.	630	570	880	IX.	400	300	1330
100°.	426	610	680	100°.			
$230 \times 10^6\omega$				$10^9\omega$			
+ 780.				+ 1330.			
VIII.	84	630	132	IX.	20	300	66
215°.	86	600	142	215°.	25	280	88
$200 \times 10^3\omega$				$700 \times 10^3\omega$	36	300	120
+ 136.				+ 93.	30	300	100
VIII.	20	740	26	IX.	— 25	300	— 83
310°.	34	725	34	310°.	— 32	300	—107
$50 \times 10^3\omega$	33	665	50	$140 \times 10^3\omega$	— 17	300	— 55
× 43.	40	640	63	—76.			

These results are shown in Fig. 20.

Digitized by Google

The specific resistance of petroleum is not so high as that of gasoline, though it is more than twenty times that of glass at 215°, and the insulation breaks down less rapidly. The pressure coefficients decrease in marked degree with rise of temperature and nearly proportionally to it, and they actually pass from positive to negative values. They are of a larger order of numerical magnitude than the glass coefficients. At 310°, where the petroleum coefficient is negative and the glass coefficient, according to Tables 48 and 50, positive, a criterion of the effect of the oil is obtainable. The glass tube[1] does not stand this test fully, since the pressure coefficients of oil and glass in series IX are both negative, though the effect of the glass is a decided algebraic increase of the oil coefficient. Moreover, as the trustworthiness of a tube like Fig. 14 reversed is no longer vouched for, I made the remaining experiments with the tube Fig. 16. I also tested a better insulating oil.

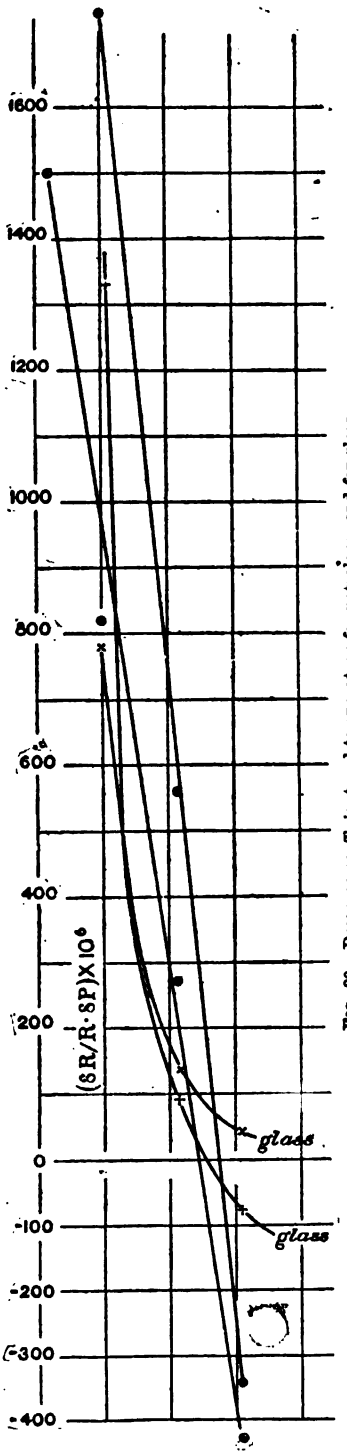


FIG. 20.—Pressure coefficient and temperature for petroleum and for glass.

101. *Pressure coefficient of thin machine oil.*—Tables 53 and 54 contain data for the insulation and resistance of thin mineral machine oil ("mineral sperm"), and also for glass surrounded by it. At 215° the resistance of the liquid is more than 50 times that of glass, and the breakdown in the former case much less rapid. Two glass tubes of the form Fig. 16 were used consecutively. In the first of these the internal and external diameters of the inner tube were 0·24 and

[1] I strongly suspect that some oil had worked itself down into the sodium amalgam, and that this is the true cause of the exceptional behavior referred to in the text. This inference was sustained by a dissection of the tube after the experiment.

Digitized by Google

0.34 centimeters, respectively; in the other the dimensions of the inner tube were those given in § 87.

TABLE 53.—*Insulation and pressure coefficient of thin mineral machine oil.*

[p_0=150 atm. Insulation at 20°, $3\times10^7\omega$.]

Series No. θ R Mean $k_r\times10^6$	$\times10^3$ δR/R	δp	$k_r\times10^6$	Series No. θ R Mean $k_r\times10^6$	$10^3\times$ δR/R	δp	$k_r\times10^6$
5.	400	410	970	5.	95	370	+260
215°.	400	420	960	†310°.	95	340	280
$320\times10^6\omega$				$50\times10^6\omega$	140	400	350
+960.				+300.	125	390	320
5.	—220	410	—525		400	410	970
*215.	—160	430	—370		400	420	960
$110\times10^6\omega$	—190	440	—430				
—440.							

* Dirty, after an explosion. † Clean, refilled.

TABLE 54.—*Pressure coefficient of glass, surrounded by mineral machine oil.*

[p_0=150 atm.]

Series No. θ R. Mean $k_r\times10^6$	$10^3\times$ δR/R	δp	$k_r\times10^6$	Series No. θ R Mean $k_r\times10^6$	$10^3\times$ δR/R	δp	$k_r\times10^6$
XI.	61	445	137	XI.	57	400	143
215°.	59	420	140	215°.	59	400	147
$80\times10^3\omega$				$190\times10^3\omega$			
+138.				+145.			
XI.	53	425	127	XI.	71	385	185
215°.	67	420	157	100°.	94	365	260
$120\times10^3\omega$				$30\times10^6\omega$	113	375	300
+143				+250.			
XI.	41	363	115	*XII.	66	395	170
310°.	48	415	116	215°.	69	395	175
$6\times10^3\omega$ to	46	420	112	$360\times10^3\omega$	63	355	175
$8\times10^3\omega$	52	410	126	+173.			
+117.	49	420	117	*XII.	54	350	155
	48	415	115	310°	60	350	170
				$26\times10^3\omega$	67	380	180
				+168.			

*Another tube of higher resistance.

Some of these results are shown in Fig. 21.

Repetitions of this work led to virtually the same uniformity of result, as is well evidenced by the close coincidence of the data for 215°. The coefficients of the two tubes, however, are not identical. A feature of Table 53 is the change of sign of the pressure coefficient when the oil has become contaminated. It is in these experiments (Table 53)

Digitized by Google

that I specially observed the apparent accommodation detailed in § 121. As a whole, the data are in reasonable conformity with Table 48.

102. *Pressure coefficient of thick machine oil.*—My final experiments were made with a very sticky *mineral* machine-oil (cf. § 83). Two tubes of the form Fig. 16, but of different resistances, were used (§ 101).

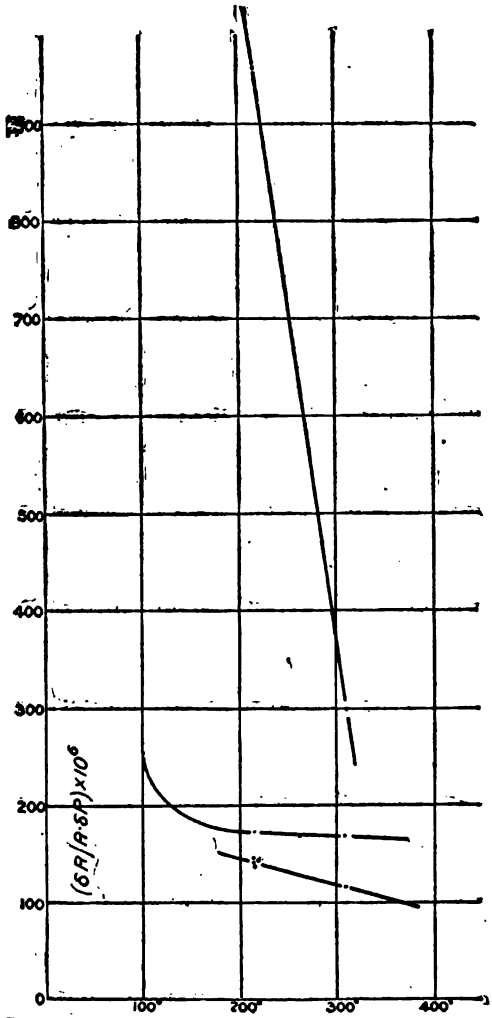


FIG. 21.—Pressure coefficient and temperature for thin mineral machine oil and for glass.

At 310° the oil coefficients are negative, whereas the glass coefficients remain distinctly positive. This seems to be a conclusive test, since an effect of the glass in changing the sign, or in anyway increasing the oil coefficients is inconceivable. The increase of the latter with pressure at 215° (cf. Table 55) is probably an actual occurrence. The two tubes again differ in their properties.

Digitized by Google

TABLE 55.—*Insulation and pressure coefficient of sticky mineral machine oil.*

[p_0=150 atm. Pressure coefficient of glass. Oil insulation at 100°, $4\times10^7\omega$.]

Series No. θ R Mean $k_T\times10^6$	$10^3\times$ $\delta R/R$	δp	$k_T\times10^6$	Series No. θ R Mean $k_T\times10^6$	$10^3\times$ $\delta R/R$	δp	$k_T\times10^6$
6.	530	810	655	XIII.	73	430	170
215°.	520	820	635	*215.	42	450	92
$130\times10^6\omega$	125	360	350	$120\times10^3\omega$	50	400	125
+510.	155	400	390	129.	Tube broken.		
6.	−140	440	−320	Tube of high resistance inserted.			
310°.	−145	410	−355				
$18\times10^6\omega$	−120	420	−285	XIV.	81	400	202
−296.	−125	450	−280	215°.	84	420	200
	−125	470	−265	$730\times10^3\omega$	165	830	200
	−115	430	−270	+205.	180	830	220
Tube of low resistance inserted.				XIV.	70	415	170
				310°.	60	420	145
XIII.	52	415	125	$36\times10^3\omega$	130	820	160
100°.	64	420	150	+155.	125	780	160
$11\times10^6\omega$	115	820	140		54	400	125
+135.	99	810	125				

* Dirty after an explosion.

These results are shown in Fig. 22.

103. *Digest.*—In Tables 56 and 57 I have briefly summarized the statistics of insulation for oil and for glass. All reference is made to 215°, since these measurements are the more reliable. The table is not intended to convey more than a mere estimate of the conditions encountered.

TABLE 56.—*Breakdown of resistance in the case of the divers oils examined.*

	Sperm oil.	Gasoline.	Petroleum.	Thin mineral machine oil.	Very thick mineral machine oil.
Specific resistance at ..... 215°	3×10^6	1800×10^6	400×10^6	1000×10^6	1200×10^6
Relative resistance at..... 20	60	10	26	300	∞
Relative resistance at..... 100	7	2	9	30	30
Relative resistance at..... 215	1	1	1	1	1
Relative resistance at..... 310	..	1	·6	·5	·1

TABLE 57.—*Breakdown of resistance in the case of divers glass arrangements.*

[Specific resistance at 215°, 19×10^6.]

Glass in—	Sperm oil.	Gasoline.	Petroleum.	Thin mineral machine oil.	Thick mineral machine oil.
100°	500	.....	1400	300	.....
215	1	.....	1	1	1
310	.....	.....	·2	·2	·05

Digitized by Google

DEDUCTIONS.

104. *Effect of pressure.*—It appears from Table 48 et seq., that the pressure-coefficient does not decrease with the size of the pressure interval δp. The tendency is rather in favor of an increase; but this is obscure. Hence the results obtained are properties of either the oil or of the glass, and not incidental disturbances. Moreover, I am war-

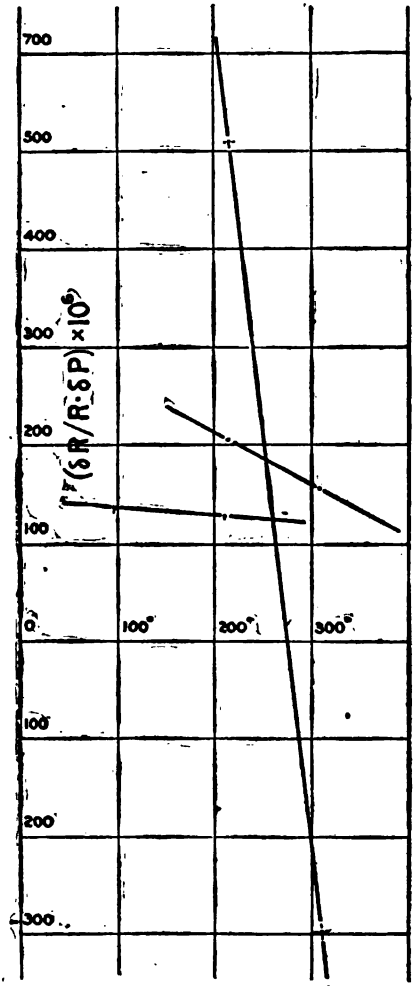


FIG. 22.—Pressure coefficient and temperture for thick mineral machine oil and for glass.

ranted in taking the means of the divers pressure coefficients found at any temperature as the probable value at that temperature.

105. *Temporary and permanent effects.*—Remarks on the discrimination of temporary and permanent effects have been made in §§ 95, 97.

Digitized by Google

106. *Chart.*—In order to obtain a clear insight into the data of Tables 48 to 55, it is best to construct pressure coefficient as a function of temperature. This has been done in Figs. 18 to 22, above. It would be more in keeping with the present work to coordinate this coefficient with resistance; but the latter data are not sufficiently accurate.

107. *Pressure and chemical equilibrium.*—Turning attention first to the behavior of the solid insulator, it appears that the electrical resistance of glass increases in very marked degree with the pressure which is brought to bear on it. In my earlier paper[1], in which I subjected glass to tensile stress (presumably dilatational), I found that the resistance had pronouncedly decreased. I also found that the results at 360° were not as evident as at 100°. Hence the present and the earlier observations, though attacking the question from opposite points of view, are in accord. I am thus justified in announcing that *the chemical equilibrium of a solid changes with each change of strain* (§ 114).

108. *Effect of temperature.*—The tables further show that the pressure coefficient of resistance decreases with rise of temperature; or that the effect of pressure decreases algebraically as the number of free ions available for the transfer of charges become greater. In an earlier paper[2] I showed that the resistance of a liquid electrolyte like zinc sulphate in water, or of a liquid metal like mercury, is a decrease of specific resistance. Finally, the present results for insulating oils contain several examples in which a passage of the positive into the negative pressure coefficient is directly observed. I conclude that the curve for glass, if prolonged, will eventually intersect the axis of temperature somewhere in the region of low red heat, and that the further course will be negative. Hence for all substances, solid or liquid, there is a point or state of electrolytic dissociation at which the effect of pressure on resistance is nil, or at which the increased molecular stability obtained by pushing the molecules nearer together, and perhaps of binding the constituents of the individual molecule more firmly together, counterbalances the decrease of the path over which the ion travels in conveying charge. Taking all the results for glass, oils, the solution, and the metal into account, it appears that the complete functionality will be given by a curve which is asymptotic both to the vertical in the region of low temperatures and positive pressure coefficients, and to the horizontal in the region of relatively high temperatures and negative pressure coefficients. The nature of this curve I have not been able to work out (§ 106), nor will it be the same for all substances.

109. *Molecular effects of stress.*—Having thus found a consistent behaviour in metals and electrolytes in relation to strain, I am prepared to accept the proposition italicized in § 107 as true for solids[3] generally.

[1] American Journal of Science (1889), vol. 37, p. 349.

[2] American Journal of Science (1890), vol. 40, p. 219.

[3] To my knowledge the only experiments on the effect of pressure on the resistance of solid metals are due to Chwolson (Carl's Repertorium, vol. 14, p. 26, 1878,) who shows that their pressure coefficient, like that of mercury, is negative.

Digitized by Google

For the case of metals Osmond[1] has partially anticipated me, stating that strain more or less completely converts cold metals from one definite molecular condition into another. I have been unable to find, however, that Osmond has any direct evidence to support this assertion, and I have already pointed out[2] some of the difficulties which Osmond must surmount before his view can gain general credence. If mechanical stress is to convert α-iron into β-iron, it is not to be overlooked that whereas the hardness called temper changes the electrical resistance of steel enormously (as much as 300 to 400 per cent), the electrical effect of mechanical strain is relatively negligible. Even though much of this discrepancy can be explained away, *direct* experiments on metals confirming Osmond's view will not be easily forthcoming. Two years ago I spent much time in endeavoring to throw light on the polymerization of metals, by studying the hydroelectrics of stretched and soft wires[3], by dissolving hard-drawn and annealed iron, by investigating the carburation changes of strained steel; but in no case have I found evidence of an indisputable bearing on the point at issue. Finally, regarding the mere statement[4] of inferences of the above kind, I believe I anticipated Osmond by interpreting viscosity in solids[4] with reference to Clausius's theory of electrolysis.

110. *Hysteresis.*—The proposition of § 107, taken in connection with my observation of the occurrence of volume lag[5], under isothermal conditions, suggests important inferences on the behavior of stress solids generally, and leads naturally to an explanation of hysteresis. If the pressure under which a liquid just solidifies, cæteris paribus, is in excess of the (positive or negative) external pressure at which it again liquefies (volume-lag[6]), and if the chemical equilibrium of the solid acted on changes with each change of strain, then, quite apart from consider-

[1] Osmond: Ann. des Mines, July-August, 1888, p. 6; Mém. de l'artillerie de la marine (Paris, 1888), p. 4. Of course I make no reference against the ingenious experiments from which Osmond infers the spontaneous conversion of α-iron into β-iron at red heat.

[2] Nature, vol. 41, 1890, p. 370.

[3] American Chemical Journal, vol. 12 (1890), page 1.

[4] Am. Jour. Sci., vol. 33, 1887, p. 28.

[5] Am. Jour. Sci., vol. 38, 1889, p. 408.

[6] A good example of the volume-lag is given by an undercooled liquid like fused thymol (melting at 53°), for instance, which at, say, 30° solidifies under about 500 atm., and does not again liquefy on removing the external pressure. I have worked with para-toluidine, naphthalene, α-naphthol, paraffin, and caprinic, palmitic, and monochloracetic acids. My original belief in the general character of these static phenomena has recently been disturbed by new experiments, in which I found for the special case of paraffin that it would be possible to be misled by *local* solidifications of the column under pressure. The volume-lag is always marked when there is even a suggestion of undercooling. The action of pressure is then similar to the closing of a door and opening it again without lifting the latch. Observations made at intervals of 20 minutes each, with palmitic acid, showed that at 60° this substance solidifies between 300 and 400 atm., and then remains solid even between 200 and 300 atm. At 100°, α-naphthol solidifies at 500 to 600 atm., and when pressure is being removed it remains solid until about 150 atm. Undercooled caprinic acid at 20° solidifies under 150 atm., remaining solid. At 33° it solidifies at about 500 atm., and then fuses again at about 200 atm. Local solidifications here suggest the occurrence of isomers or other impurity. Sometimes, as in the case of naphthalene, the volume-lag is not thoroughly static, but becomes viscous in character, etc. I have yet to study the effect of temperature on the magnitude of the volume-lag, i. e., on the difference of pressures isothermally corresponding to solidification and to fusion. Very large pressure-intervals are essential for this purpose.

Digitized by Google

ations *directly* involving the second law of thermodynamics, quite apart from the energy dissipated in the cycle, the solid at identical stress points needs not to be in the same chemical condition while stress is being removed in which it was when stress was being applied; for there will be certain groups of particles, uniformly distributed throughout the solid, which during the "stress-on" phase pass from a first molecular condition to a second, and which, in virtue of the volume-lag, do not regain their original state at identical pressures of the "stress-off" phase. The march in the two cases is not a symmetrical one. This I take to be the inherent nature of the phenomena studied by Cohn[1], Warburg[2], and others, and to which Ewing[3], after much original research, has given the generic name hysteresis. In my note I pointed out the important bearing of the volume-lag on the molecular behavior of matter[4], though I have yet to specify my views in detail. The occurrence of hysteresis therefore implies a favorable molecular mechanism of the kind indicated, and one would not expect to find it at once in all substances.

Conformably with the above, the interpretation given by Mr. C. A. Barus-Wilson[5] of his important discovery (to which I alluded in a former paper) is much more than an analogy.

111. *Magnetic hysteresis.*—Warburg and Ewing have proved that hysteresis is not only associated with mechanical stress, but may be very clearly evoked by magnetic stress. Curiously enough, the evidence in favor of the views expressed in § 26 is here directly forthcoming. Remsen's[6] discovery of the chemical influence of the magnetic field, additionally substantiated as it now is by the ingenious experiments of Rowland and Bell[7], proves beyond a doubt that magnetic iron is more electro-negative than unmagnetic iron. Conformably with the above paragraphs, I therefore infer that this phenomenon is to be interpreted as directly evidencing a chemical difference between magnetic and unmagnetic iron, and as such I consider it an exceedingly important step towards an ion theory of magnetism[8]. Thus the occurrence

---

[1] E. Cohn: Wied. Ann., vol. 6, 1878, p. 388.
[2] Warburg: Wied. Ann., vol. 13, 1881, p. 141.
[3] Ewing: Phil. Trans., vol. 2, 1885, p. 545.
Am. Jour. Sci., vol. 38, 1889, p. 408.
[5] Barus-Wilson: Phil. Mag., vol. 29, 1890, p. 200.
[6] Remsen: Am. Chem. Jour., vol. 3, 1881, p. 157.
[7] Rowland and Bell: Phil. Mag. [5], vol. 26, 1888, p. 105.
[8] In Nature (vol. 41, 1890, p. 370) I pointed out that closed helical paths of molecular dimensions, consisting of a right and a left hand screw-thread, with their ends joined, can be generated by symmetrical interpenetration of two congruent Bravais nets. I inferred that electrical charges travel along and around the said closed helical paths by the action of the magnetic field could be made to replace the usual conception of molecular currents circulating in a molecule without resistance. From this point of view magnetic and electric fields merely differ in the rotational character of the former as compared with the nonrotational character of the latter. Whereas in an electrolyte the dissociation takes place as the result of chemical relations and heat, it takes place in a metal under the sole influence of heat. The immediate action of both fields is directional; and by taking advantage of the positions of labile equilibrium of the ion, they act in a way analogous to Clerk-Maxwell's

Digitized by Google

of the chemical difference in question, and the explanation of magnetic hysteresis, as given in the present and preceding paragraphs, mutually sustain each other.

112. *Mechanism of viscosity.*—Whether viscosity and dissociation in solids are to be explained with reference to a single mechanism, or whether we are to conceive of two mechanisms (molecular and atomic frameworks), one, as it were, within the other, is at the present stage of research a mere question of special convenience. The remarkably low viscosity at the yield-points of metals, as well as the similarly low viscosity near the Gore-Barrett phenomena, are both in conformity with the sudden passage from a first molecular state to a second, through an instability.

It may be well to point out the bearing of the singular minimum[1] of the viscosity of hot iron on the interpretation given of Maxwell's theory,[2] more explicitly. When iron passes through Barrett's temperature of recalescence, its molecular condition is for an instant almost chaotic. This has now been abundantly proved.[3] The number of unstable configurations, or, more clearly, the number of configurations made unstable because they are built up of disintegrating molecules, is therefore at a maximum. It follows that the viscosity of the metal must pass through a minimum. Physically considered the case is entirely analogous to that of glass-hard steel suddenly exposed to 300°. If all the molecules passed from Osmond's β to his α state together, the iron or steel would necessarily be liquid. This extreme possibility is, however, at variance with the well-known principles of chemical kinetics. The ratio of stable to unstable configurations can not at any instant be zero. Hence the minimum viscosity in question, however relatively low, may yet be large in value as compared with the liquid state.

In a preceding bulletin (No. 73) I have shown that to explain the varied physical phenomena which accompany temper, it is sufficient to recognize some special instability in the tempered metal. This condition is given by the carbide configuration, and the physical explanations in question may be made without specifying its nature further. The essentially chemical nature of this phenomenon is, however, not to be ignored. Seeing that the amount of carbon contained in steel is not large, the electrical resistance of hard steel is at once an expression of its chem-

---

demons ("Heat," chap. XXII, § 10), producing marked effects at the expenditure of a relatively small amount of work.

The advantage which I seek for in this tentative suggestion has direct reference to my own line of work. I can picture to myself the rôle played by the *foreign* ingredient chemically present in iron, in modifying the retentiveness and the magnetic stability of the metal. Thus I conceive the carbon atoms in hard steel to be so placed that after magnetization they block out definite closed helical paths in the metal, along which the transfer of charges must thereafter take place. Hence an increase of magnetic stability as contrasted with pure iron, where from any point four or more such paths may be open. Again, other substances (manganese, say) may be conceived to unite with the iron in such a way as to shut out the possibility of closed helical paths altogether. The fact that my permanent magnet is essentially a self-exhausting engine does not seem to be a serious objection.

[1] Roberts Austin: Nature, vol. 41, 1890, pp. 11, 34.

[2] Barus: Bulletin, U. S. Geol. Sur., No. 73, 1891.

[3] Cf. John Hopkinson: Phil. Trans., London, vol. 180, p. 443, 1889, where the literature may be found.

Digitized by Google

ical composition, structurally unknown though it be. Hence in the electrical diagram of the phenomena of temper, constructed by Dr. Strouhal and myself,[1] the time variations of resistance of hard steel at any given temperature may be interpreted as a case of Wilhelmy's[2] rate of chemical reaction, and expressed in accordance with his well-known exponential law. This indeed is the character of the observed curves. Hence also the full diagram of the phenomena of temper, considered both in their variation with time and with temperature, is available for the elucidation of moot points relative to the effect of temperature on rate of chemical reaction.

From all that has been said it is clear that the mechanisms of viscosity and of diffusion (electrolysis), though containing a similar thermal factor, can not be quite the same. Thus it has lately been shown by Reformatsky[3] that the speed of the same reaction in a jelly and in a water medium do not appreciably differ. On the other hand diffusion in solids is essentially a slow process. Studying the colored oxide coats on iron, Dr. Strouhal[4] and I pointed out that the outer surface of the film is oxidized as highly as possible in air; and that the inner surface of the film, continually in contact with iron, is reduced as far as possible. This distribution of the degree of oxidation along the normal to the layer, is equivalent to a force in virtue of which oxide is moved through the layer, from its external surface to its internal surface. The formation of an oxide coat is thus a case of diffusion. Conformably with this view, the film, during its formation, behaves like an electrolyte, as was discovered and substantiated by Franz, Gangain, and Jenkin, and more recently by Bidwell and by S. P. Thompson. We then adverted to the crucial difference between diffusion in solids and diffusion in liquids, inasmuch as in the former case (solids) diffusion demonstrably ceases after a certain small thickness is permeated. The limit thickness of the film is reached asymptotically through infinite time. It has a definite value for each temperature, increasing as temperature increases. In the light of other information since gained this explanation is substantiated. The formation of the oxide coat is a case of solid diffusion, and as such it bears the same relation to the diffusion of liquids that the viscosity of solids bears to the viscosity of liquids. The two phases (solid, liquid) of each phenomenon are to be correlated in ways essentially alike. The available stress, as compared with the available instability, determines the time character of the result.

To recapitulate: In the usual cases of viscosity there are presented to us cases of localized destructions of configurations, the integrant parts of which are stable molecules. In the case of chemical interaction between contiguous configuration (diffusion, electrolysis) consist-

[1] Bulletin, U. S. Geol. Sur., No. 14, chapter II, 1885.
[2] Wilhelmy: Pogg. Ann., vol. 81, 1850, pp. 413, 499.
[3] Reformatsky: Zeitschr. f. phys. chem., vol. 7, 1891, p. 34.
[4] Bull. U. S. Geol. Sur., No. 27, 1886, p. 51.

Digitized by Google

ing either of an exchange of atoms or of molecules, there need be no viscous effect, provided the exchange is perfectly reciprocal. In the case of irreciprocal interaction, finally, by which molecules are left in the lurch and broken up, the configuration of molecules will also be modified, and hence a viscous effect appears. Examples of all these cases are frequent in the above text.

113. *Electrical effects of æolotropic stress.*—It follows from tables 48 to 55, that in an æolotropically strained transparent solid like glass, electric conduction is different in different directions, the difference depending on the intensity of strain. Suppose this be considered in connection with the doubly refracting property of such a solid, and again with Warburg and Tegetmeier's[1] researches on the electric conduction of quartz along its optic axis, with nonconduction at right angles to it. Then the inference is tenable, that the strain artificially sustained in one case is naturally sustained in the other. Tegetmeier's conducting sodic silicate, ingrained in the crystalline structure of quartz, and possessing larger molecular conductivity in quartz than in glass, may be looked to as responding to strain of the kind suggested.

UNAVOIDABLE ERRORS.

114. *Polarization.*—In the next six paragraphs it will be convenient to discuss some of the errors relating to both the measurements of resistance and electromotive force.

The effect of pressure on the polarization occurring in case of the above cell and of exceedingly weak currents is somewhat difficult to handle. Warburg[2] and others have shown that the reaction is essentially Na/glass/Hg changing to Na Na_2SiO_3glass/NaHg, or a mere transfer of sodium through the walls of the glass, by aid of sodium silicate as a conveyancer. I shall therefore have to rely on the data of Table 49, in which, if a marked effect of pressure on polarization had been present, it would have been detected. It will be remembered that I commenced with high initial pressures (p_0=50 to 200 atm.) to obviate incidental disturbances.

115. *Insulators.*—The effect of pressure on the oil in the piezometer was specially investigated in each case. Cf. Tables 50 to 55, § 122.

116. *Shifting isothermal planes.*—A source of error is introduced by the temporary shifting of the isothermal planes of the piezometer, during compression, in virtue of the compressibility of the oil contained in the tube. Adiabatic thermal changes during compression or removal of pressure would produce effects of a sign opposite to those of the tables.

To remove both of these it was often my habit to wait 3 to 5 minutes.

[1] Warburg and Tegetmeier: Wied. Ann., vol. 35, 1888, p. 455; vol. 41, 1890, p. 18.
[2] Warburg: Wied. Ann., vol. 21, 1884, p. 622; vol. 35, 1888, p. 455.

Digitized by Google

supposing the original thermal state was then nearly enough regained. Longer waiting was not safe because of fluctuations of the astatic system of the galvanometer.

Special tests were made as follows: In Fig. 23 let P Q be the piezometer closed at Q, and receiving pressure in the direction of the arrow. Let A B be the position of the glass resistance tube. Finally, let the hollow cylindrical vapor bath surrounding the piezometer stretch respectively from *b* to *d*, or from *a* to *c*, or from *c* to *e*. Parts lying within the vapor bath have constant temperature, which falls off rapidly from both ends of the bath towards the ends of the piezometer. When pressure is applied the vertical isothermal planes of the compressible oil are all moved from P to Q. With the vapor bath in the position *b d*, pressure would thus cool the end A and heat the end B of the glass tube A B; but the cooling would exceed the heating. Hence an error of the sign of the data, Table I, etc. Now let the vapor bath be shifted to the position *a c* and the thermal state be steady. The B-half of the tube A B is now exposed to cold, and compression can only have the effect of heating these parts, seeing that the A-half is protected.

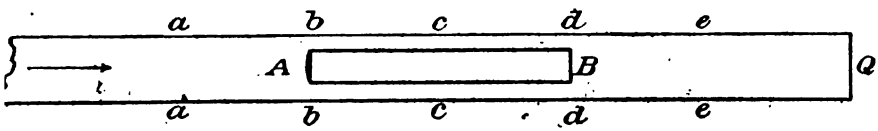


FIG. 23—Diagram.

Hence an error of a sign *opposite* to the data of Table 48, etc. Finally, when the bath has the position *c e*, the error first considered would be accentuated.

I made experiments in accordance with this scheme at 310°, but found that this severe test did not change the character of the results of Table 48. Data are superfluous. Again, decreasing the length of the tube A B had no appreciable effect. Similar tests were made with reference to Table 49.

117. *Electromotive force.*—It is clear at the outset, since pressure increases both the resistance of glass and the electromotive force NaHg/glass/Hg, that changes of the latter will act in a way tending to wipe out the change of resistance. Let *e*, I, R denote the electromotive force, current, and resistance of the uncompressed circuit. Let I_p be the current corresponding to pressure p, and k_R and k_e be, respectively, the pressure-coefficients of resistance and electromotive force. Then

$$k_R = (I(1 + k_e p) - I_p)/p \,.\, I_p \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Table 49 gives $k_e = 10 \cdot 10^6$, say, whence the values of Table 58 result from Table 48, series III (cf. § 95). In the final column $k'_R = \delta R/R \,.\, \delta p$, the former coefficient.

Digitized by Google

TABLE 58.—*Allowance for increments of electromotive force.*

[$\theta = 215°$.]

p	$10^3 p \cdot k_e$	$I(1+pk_e)$	I_p	$10^6 \times k_R$	$10^6 \times k'_R$
523	5.2	21·18	19·47	168	157
995	9·9	21·28	18·11	175	164
1411	14·1	21·37	17·27	168	156
512	5·1	21·18	19·39	180	169
1016	10·2	21·28	18·07	172	163
1403	14·0	21·37	17·28	169	156

Thus the data underlying §§ 106, 107, 108 are accentuated. At 310° a permanent pressure-coefficient k_e could not be detected, and at 100° it is certainly very much in error (§ 118). Since therefore k_e is never fully vouched for, I have omitted it in the computation of k_R altogether.

118. *Short circuiting.*—In case of an uncompressed circuit shunted by unavoidable leaks, let R_1, R_2, R_3 be the resistances of the cell, the shunt, and the metallic circuit respectively. Similarly let i_1, i_2, i_3 be the three partial currents corresponding respectively to R_1, R_2, R_3. Let $\delta R_1/R_1$ be the effect of pressure on the resistance of the cell (resistance tube), and $\delta e/e$ be the simultaneous increment of electromotive force. Finally, in case of the compressed circuit, let accentuated symbols replace the symbols for the uncompressed cell. Then a somewhat tedious reduction leads to

$$R_1/R_1 = \frac{i_3(1+\delta e/e) - i_3'}{i_3'} \frac{(1+R_2/R_1)(1+R_3/R_1) - 1}{R_2/R_1 - (n-1)R_3/R_1}, \quad \ldots \quad (2)$$

$$\delta e/e = \frac{i_3'}{i_3} \frac{(\delta R_1/R_1)(R_2/R_1 - (n-1)R_3/R_1)}{(1+R_2/R_1)(1+R_3/R_1) - 1} - \frac{i_3 - i_3'}{i_3}, \quad \ldots \quad (3)$$

where $\delta R_1/R_1 = n\delta R_2/R_2$, and $\delta R_2/R_2$ is the pressure coefficient of the oil through which the leakage obviously takes place. Regarding $\delta R_1/R_1$ in (2), if the resistance, R_3, of the metallic circuit is relatively small, or if R_1 be reasonably small relative to the leak R_2, the considerations of § 111 at once apply. The case of $\delta e/e$, however, is serious. Supposing, again, that R_3/R_1 and R_1/R_2 are small, the last equation reverts to

$$-\delta e/e = (i_3 - i_3'(1+\delta R_1/R_1))/i_3,$$

and thus the changes of resistance due to pressure are interpreted as changes of electromotive force. Zero or even electrometric methods will only measure the difference of potential of two points of the leak-shunted circuit. Hence the permanent pressure coefficients ($\delta e/e$) of Table 49 can not but be regarded with suspicion, and they are merely an essential justification of Table 48 et seq.

119. A final difficulty in case of short circuiting is not to be lost sight of. A leak usually includes an electrolyte between two different metals, and thus introduces an electromotive force in a way quite beyond computation.

120. *Electromotive force and pressure.*—The consideration of the data

Digitized by Google

of Table 49 would now be in order; but for the reasons just stated I hold the work scarcely ripe for discussion, and will therefore withhold remarks until I can devise some more nearly faultless method of measurement.

121. *Graphic representation.*—In order to exhibit the full character of the individual observations of Tables 48 to 55, I shall discuss a series of data which I was first inclined to interpret as an electrical manifestation of volume "accommodation" (§ 101). In Fig. 24, A, B, C, the ob-

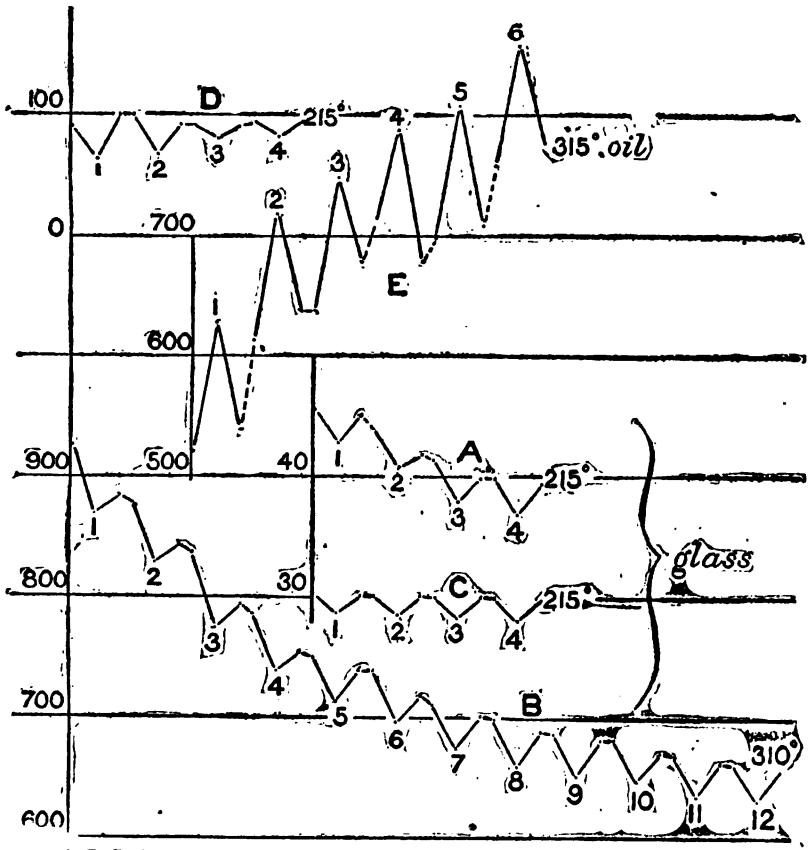


FIG. 24.—A, B, C: Charts showing the oscillation of the electric conductivity of glass with pressure at 215°, 310°, and again at 215° respectively. Experiments made consecutively. D, E: Charts showing the oscillation of the electric conductivity of very vicious hydrocarbon oil ("mineral machine oil") with pressure, at 215° and 315° respectively.

served intensities of current in relative measure are given as ordinates. They are therefore inversely proportional to the resistance of the glass. The abscissæ are times, supposing that the times consumed in making each triplet of observations are equal and similar. The oscillations are due to the fact that pressure is raised from about 150 atmospheres to about 600 atmospheres, and then lowered to the first value again, thus giving the three points for each of the triplets numbered.

Digitized by Google

In Fig. 24, D, E, similar results are given for thick mineral machine oil. In the former, pressure was twice increased from about 160 to 980 atmospheres and back again; and then from about 160 to 540 atmospheres, thus obtaining amplitudes of different values. In E pressure oscillated between about 150 and 600 atmospheres.

A, B, C, which were obtained consecutively, show a gradual decrease of resistance to a limit, very obviously in A at 215°, quite as obviously in B at 310°, but not obviously, if at all, in C. Hence the inference is suggested that the continued exposure to strain alternations at 310° has wiped out all viscous instability possible at 215°. The volume elasticity of the glass, so far as its chemical manifestations are concerned, is now constant. The objections to this interpretation are twofold. In the first place the amplitudes of oscillation are constant throughout, cæt. par., and do not converge to a limit. Again, the results for oil show similar phenomena, not very obviously in D, but marked in E, where both the negative pressure coefficient and the resistance decrease act together to invert the figure.

122. *Electric instability of hydrocarbon oils.*—I have finally to refer to the results obtained with highly-insulating liquids. It appears from these that the effect on resistance of an additional number of molecules splitting up in consequence of the removal of a fixed amount of pressure, decreases rapidly with the total number splitting up, where the decrease is to be taken in an algebraic sense and to include a march through zero. In the case of sperm oil, gasoline, petroleum, thin and thick hydrocarbon machine oil, the observed pressure coefficients pass from positive towards or actually into negative values as temperature increases, and at a rate which for the same oil between 20° and 300° is nearly constant.

These rates ($\delta R/R . \delta p . \delta\theta$) are as follows:

TABLE 59.—*Rate of thermal variation of pressure coefficient.*

Sperm oil.	Gasoline.	Petroleum.	Thin mineral machine oil.	Thick mineral machine oil.
$-3/10^6$	$-9/10^6$	$-6/10^6$ $-10/10^6$	$-7/10^6$	$-6/10^6$

The figures therefore denote the change of the pressure coefficient per degree centigrade. In a general way it may be noted that this change is least in sperm oil, where ions are present in greatest number.

Similar remarks were made in my earlier paper[1], after an examination of mercury and solution of zinc sulphate. Both coefficients in this case were negative, and I was not prepared for the positive coefficients ($\delta R/R . \delta p$) so marked in the present paper. The data as a whole, therefore, show that it is not permissible to pass from one substance to another; doubtless because the number of molecules which must

[1] Am. Jour. Sci., vol. 40, 1890 p. 222.

Digitized by Google

split up per unit of area to discharge the field varies largely from substance to substance. Inferences are to be drawn from one and the same solvent, either electrolytically dissociated by temperature, or modified by the solution of some given substance, or both.

123. The remarks of § 122 are substantiated by the incidental results of Table 53, where the number of ions is increased by dissolved dirt. It agrees with the negative pressure coefficient found for zinc sulphate (loc. cit.). Moreover, by keeping the thick machine oil at 310° for two or more hours, I found that its resistance continually decreased, while the pressure coefficient passed from indistinctly positive to pronounced negative values. Dissociation is here to be inferred.

I have only touched upon this question in passing; but if it can be proved that the occurrence of negative pressure coefficients is an index of solution, then metals may also be regarded as holding ions in solution. In general a sequence of changes of state or of molecule corresponding to gas-liquid, liquid-solid, may be regarded as crowded into the solid state, though the external manifestations are here no longer obvious at once.

124. *Conclusion.*—The present research has been excessively tedious and elusive. Moreover the final values for the pressure coefficient of glass (Tables 54, 55), although consistent, do not show the uniformity in values which I had hoped to reach. Nevertheless the results are marked, and unless there be some occult behavior of polarization, I do not believe that I have been led astray in my inferences. In so far as the results are correct, they contain the first direct and connected evidence of the change of chemical equilibrium with strain.

Regarding the behavior of liquid insulators like the hydrocarbon oils, the results found present many points of interest, and I have no doubt that a more systematic study of the subject than I have been able to make would throw much light on the details of the mechanism by which electricity is conveyed.

Digitized by Google

Digitized by Google

INDEX.

A.

Page.

Colotropy, electric effect of 130
Annealing, motional 30, 32, 38
Annealing, thermal 37
Annealing (secular), of steel 74
Apparatus for testing viscosity under strain 18
Apparatus for electrolyzing glass, etc. 81, 82, 86, 88, 90, 97, 110, 111, 112
Apparatus for measuring potentialized energy 10
Apparatus for electrolyzing oil 113
Auerbach on hardness 27

B.

Bibliography of mechanical strains 17
Bibliography of electrical resistance of glass 85
Braun on molecular change 29
Breakdown of resistance in oils and glass. 123
Breakup, kinds of 30
Brotomley, experiments of 75

C.

Carbon, how estimated 41, 44, 46
Carburation affected by strain 40, 42
Carburation, results for, discussed 44
Carus-Wilson, views of 72, 127
Cohn on cyclic traction 127

D.

Dilation promotes solution 58
Dilation, mechanism of 129
Duane, views of 40, 61

E.

Electromotive force changed by pressure 116, 132
Energy potentialized in strains 101, 105, 107
Equilibrium (chemical) of solids 109
Erg on hysteresis 126, 127

G.

Gasometer, adjustment for Thomson's 114
Gasoline, pressure electrics of 117, 123
Glass, electrical resistance of 85, 91
Glass, pressure electrics of 109, 123

H.

Page.

Hardness defined by Hertz 27
Helical paths for ions 128
Hertz on hardness 27
Hydroelectric effect of strain, of magnetization 63
Hydroelectric effect of strain discussed .. 69, 70
Homogeneity of steel, how tested 75
Hysteresis 126, 127

I.

Instability, electric, of hydrocarbon oils. 134
Insulators of oil, electrics of 130
Ion theory of metallic conduction 73
Ion theory of magnetization 127, 128

M.

Magnetization, hydroelectric effect of ... 63
Magnetization, theory of 127, 128
Maxwell's theory of viscosity 17
Mechanism of viscosity 128
Metallic conduction, ion theory of 73
Molecular change, electrically studied .. 63

O.

Oils, pressure coefficient of electrics of .. 134
Osmond, views of 27, 47, 61, 72, 126

P.

Petroleum, pressure electrics of 118, 120, 122, 123
Polarization changed by pressure 130
Pressure, effect of, on electrolytic resistance 124, 133

Q.

Quincke, experiments of 83

R.

Recalescence 27
Remsen, experiments of 63, 127
Residual viscosity 39
Resistance, electrical, of stressed glass .. 85, 91
Resistance, electrolytic, changed by pressure 124, 133
Rowland, experiments of 63, 127

Digitized by Google

S.

Page.

Secular annealing of cold steel 74
Shunts, errors due to 132
Solids, chemical equilibrium of 109, 125
Solution, method of measuring 48
Solution, rate of 48, 58
Solution, data for, of steel 49
Solution of steel, digest for 59, 60
Sperm oil, pressure electrics of 115, 117, 123
Strain, hydroelectric effect of 63
Strained wires, viscosity of 28, 31
Strains, mechanical, bibliography of 17
Strains, energy potentialized in 101, 105, 107
Strouhal on temper 79, 129

T.

Temper related to viscosity 31
Theory of magnetization 127, 128
Thomson, views of 82, 99
Torsion changes electrical resistance of glass 91, 95, 99
Traction, cyclic 25
Traction changes electrical resistance of glass 91, 95, 99
Twisting, cyclic 33, 37

V.

Viscosity, Maxwell's theory of 17
Viscosity of drawn wires 20, 23
Viscosity of stretched wires 23, 24
Viscosity of electrolyzing glass 80
Viscosity, mechanism of 123
Volume lag, examples of 126

W.

Warburg electrolyzes glass 81, 85
Warburg on cyclic magnetization 127
Wassmuth, experiments of 106

C

Digitized by Google

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 95

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

ARTHQUAKES IN CALIFORNIA

IN 1890 AND 1891

BY

EDWARD SINGLETON HOLDEN

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Letter of transmittal	7
Introduction	9
Instruments	9
Scale of measurements	10
Differences of intensity	10
Stations	12
Chronological record, 1890	12
Chronological record, 1891	20

Digitized by Google

Digitized by Google

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., February 2, 1892.

SIR: I have the honor to transmit herewith a manuscript entitled "Earthquakes in California in 1890 and 1891," by Edward S. Holden, and recommend its publication as a bulletin. It is the second of a series furnished the Survey by the Lick Observatory, the first having been prepared by Prof. J. E. Keeler and published by the Survey as bulletin No. 68.

Very respectfully,

G. K. GILBERT,
Chief Geologist.

Hon. J. W. POWELL,
Director.

Digitized by Google

Digitized by Google

EARTHQUAKES IN CALIFORNIA IN 1890 AND 1891.

By EDWARD S. HOLDEN.

INTRODUCTION.

The following paper is a continuation of records of the same kind by Prof. Keeler and myself[1] and it brings the list up to the end of the year 1891. It records all the shocks observed or felt on Mount Hamilton, and all those reported to the Lick Observatory by letter, as well as newspaper reports of such earthquakes as occurred in the state during that year. No systematic examination of the newspapers has been made, however, and reports may have escaped notice.

INSTRUMENTS.

The instruments used for recording earthquakes on Mount Hamilton are described in Publications of the Lick Observatory, vol. I, p. 82. The largest and most complete instrument records the north and south, east and west, and vertical components of the earth's motion, separately, on a smoked glass plate, which is started by the preliminary tremors of the earthquake and rotates uniformly in about three minutes, the edge of the plate being graduated into seconds at the same time by the clock, which also serves to record the time of occurrence of the shock. This instrument has been called the Ewing seismograph in the notes. Another simpler form consists of the heavy "duplex" pendulum adjusted to a long period of vibration, with a magnifying pointer or pen, which records on a smoked glass plate both horizontal components of the motion. The vertical component and the time are not recorded. The motion of the earth is magnified 4.0 times in the duplex seismometers.

The observatory possesses other seismographs of various patterns, but they are not constantly in use.

[1] List of recorded earthquakes in California, Lower California, Oregon, and Washington Territory (from 1769 to 1888.) Sacramento: State Printing Office.
Earthquakes in California in 1888. American Journal of Science, vol. 37, May, 1889.
Earthquakes in California in 1889. Bulletin U. S. Geological Survey No. 68, 1890.

Digitized by Google

SCALE OF MEASUREMENTS.

In the record made by the Ewing seismograph both horizontal components are magnified 3·3 times, and the vertical component is magnified 1·6 times. The measures of the vibrations as given in the notes are taken directly from the tracings, and therefore represent the magnified motion.

If both the period T, and the amplitude a of an earthquake wave are given, the maximum acceleration due to the impulse, which may be taken as a measure of the intensity or destructive effect of the shock, is given by the formula—

$$I = \frac{4\pi^2 a}{T^2}$$

in which the motion is assumed to be harmonic.

DIFFERENCES OF INTENSITY.

Estimates of the intensity of shocks are also given (in Roman numerals inclosed in parentheses) according to the Rossi-Forel scale, which for convenience of reference is inserted below. Experience has suggested that for observations in California a few additions should be made to this scale, and these are printed here in *italics*. When these are in quotation marks also, they are expressions actually used in the newspapers, etc., in describing earthquake shocks, whose intensity is otherwise known. The scale, as amended, is as accurate as anything of the kind can be.

I.

Microseismic shocks recorded by a single seismograph, or by seismographs of the same model, but not putting seismographs of different patterns in motion; reported by experienced observers only.

II.

Shock recorded by several seismographs of different patterns; reported by a small number of persons who are at rest. "*A very light shock.*"

III.

Shock reported by a number of persons at rest; duration or direction noted. "*A shock;*" "*a light shock.*"

IV.

Shock reported by persons in motion; shaking of movable objects, doors, and windows; cracking of ceilings. "*Moderate;*" "*strong;*" "*sharp;*" (sometimes) "*light.*"

Digitized by Google

V.

Shock felt generally by everyone; furniture shaken; some bells rung. *Some clocks stopped; some sleepers waked; "smart;" "strong;" "heavy;" "severe;" "sharp;" "quite violent."*

VI.

General awakening of sleepers; general ringing of bells; swinging of chandeliers; stopping of clocks; visible swaying of trees; some persons run out of buildings. *Window glass broken; "severe;" "very severe;" "violent."*

VII.

Overturning of loose objects; fall of plaster; striking of church bells; general fright, without damage to buildings. *Nausea felt; "violent;" "very violent."*

VIII.

Fall of chimneys; cracks in the walls of buildings.

IX.

Partial or total destruction of some buildings.

X.

Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

The relation between the intensity (I) of a shock as determined by the formula already given, and the numbers of the Rossi-Forel scale, has been reduced from all available data up to 1888, and is given below in tabular form. It is, of course, a rough approximation only.

Rossi-Forel scale.	Intensity.	Difference.
	mm. per sec.	
I.....	20	.....
II.....	40	20
III.....	60	20
IV.....	80	20
V.....	110	30
VI.....	150	40
VII.....	300	150
VIII.....	500	200
IX.....	1,200	700

One of the objects of the earthquake observations on Mount Hamilton is to obtain data for correcting this table, so that the intensity of a shock, as defined mathematically by the formula $I=\frac{V^2}{a}$ (where V is the maximum velocity of the vibrating particle), can be inferred from the ordinary descriptions of its effects.

Digitized by Google

STATIONS.

A number of duplex-pendulum seismographs, quite similar to the one used at the Lick Observatory, are placed at different points on the Pacific coast, but they are not all in operation. The stations are:

Student's Observatory, Berkeley, in charge of Prof. Soulé.

Chabot Observatory, Oakland, in charge of Mr. Burckhalter.

Private observatory of Mr. Blinn, in East Oakland.

Observatory of the University of the Pacific, San Jose.

Observatory of Mills College, near San Francisco, in charge of Prof. Keep.

Office of State Weather Bureau, Carson, Nev., in charge of Prof. Friend.

The reports of the United States Light-House Board and of the United States Signal Office (United States Weather Bureau) for 1890 and 1891 record a number of shocks not mentioned in the following list, and they should be consulted in this connection.

Prof. Keeler was in charge of the earthquake instruments of the Lick Observatory during 1890 and 1891. Most of the following statistics were, however, collected by myself. Dr. Henry Crew has kindly put them in chronological order, as follows:

CHRONOLOGICAL RECORD, 1890.

January 15.—MOUNT HAMILTON, 5:05:±1m. a. m. (Prof. Holden).—Intensity =V— Rossi-Forel scale. Mr. Keeler was partly awake at the time, and counted one minute from the beginning of shock, and noted time by watch, P. S. T.[1] = 5:05:3±10s. a. m. Intensity = IV. Rossi-Forel scale. Time by earthquake clock = 5:02 a. m.

The record of the duplex seismograph shows the actual displacement of the pendulum bob to have been 2·6 mm., in a direction almost exactly northwest and southeast. The record consists of a single nearly straight line.

SAN JOSE.—Two shocks felt about 5 o'clock a. m., sufficiently heavy to awaken sleepers; from north to south.

January 18.—NAPA.—Two slight shocks. Vibrations from north to south.

SANTA BARBARA, 3:30 p. m.—Reported in the Chronicle as "quite a heavy shock."

January 23.—CHABOT OBSERVATORY, 4:18±1 m. a. m.—Time observed by George B. Fox. The seismographic record accompanying the report indicates the total actual displacement of the pendulum to have been 2·8 mm., in a direction from "north by east" to "south by west." The tracing is made up of five small waves (small with reference to the total length of the tracing), which look as if they might

[1] P. S. T. = Pacific slope time.

Digitized by Google

have resulted from a simple harmonic motion having displacements in an east and west direction.

January 24.—SANTA ANA.—The San Jose Mercury reports this as follows:

"SANTA ANA, January 24.—A very distinct earthquake shock, lasting 4 seconds, was felt this afternoon at 1:15, and at 4:30 o'clock there was a larger and more pronounced shock, lasting ten seconds. The direction was northeast and southwest."

February 5.—SAN DIEGO, 10:15 p. m.—"Distinct shock; vibrations from east to west."

SANTA ANA, 10:14 p. m.—"Shock lasted eight seconds. Vibrations from northeast to southwest."

SAN BERNARDINO.—"Three distinct shocks, preceded by a low rumbling noise. The shock (?) lasted for four or five seconds."

The above three reports are all from newspapers.

February 9.—SAN BERNARDINO.—Following is the report published in the Times-Index of San Bernardino of February 10:

"Quite a heavy shock of earthquake visited this section yesterday morning at 6 minutes past 4 o'clock. The vibrations were north and south, and the shock caused a great many persons to arise much earlier yesterday morning than heretofore."

Under this date the Examiner, of San Francisco, reports the following:

"SAN PEDRO, February 9.—Three mild but distinct shocks of earthquake were felt at San Pedro at 4:07 o'clock this morning. The vibrations lasted for several seconds and were from east to west.

"COLTON, February 9.—A heavy shock of an earthquake was felt in Colton at 4 o'clock this morning.

"POMONA, February 9.—At 4 o'clock this morning three distinct shocks of an earthquake were felt here. Nearly every one was roused from his slumbers, but little damage was done. In the Progress office type was 'pied,' and some panes of glass were broken about the city.

"SAN DIEGO, February 9.—Another shock of an earthquake was felt in this city at 4 o'clock this morning. It lasted about a minute, and was accompanied by rumbling noises."

February 13.—TEHACHAPI, 2:10 a. m.—The following is from the San Bernardino Times-Index:

"TEHACHAPI, February 13.—Three light but distinct shocks of earthquake were felt here about 2:10 this morning. They occurred at intervals of about twenty minutes. The second shock lasted several seconds."

February 15.—LOS ANGELES, about 4 a. m.—Reported as follows in the Los Angeles Herald of February 16: "Residents in this city and dwellers in its suburbs generally were very rudely awakened from their slumbers yesterday morning at about 4 o'clock. A long, low rumbling noise as of distant thunder along the crests of the mountains was heard

Digitized by Google

by people who were awake at that hour, and this was soon followed by a very decided shock of earthquake. Houses shook, windows rattled, pictures vibrated on their hooks, and it was only very sound sleepers who were not roused to full consciousness that the giant tread of the shaker was abroad. The oscillations were of a long, steady character rather than of the short, jerky order often felt in earthquake movements. The vibrations were nearly from northeast to southwest, and were separated into three distinct divisions. The first was the heaviest, followed by another lighter one at a short interval, and then, after a pause, a third little kick, less pronounced than the others. This is the second shock in this section within a year. In old days it was noted for its frequent seismic manifestations, but for forty years they have not been pronounced. Their center is near the San Jacinto peak."

GILROY, midnight.—A light shock.

April 11.—UKIAH, 11:30 a. m. (?)—Vibrations from southeast to northwest.

April 15.—MOUNT HAMILTON, 2:00 a. m.—No record but the tracing of the duplex seismograph, which is an almost perfectly straight line running northwest and southeast. The total actual displacement of the pendulum bob is 1·9 mm.

April 24.—MOUNT HAMILTON, 3:36 a. m.—The duplex seismograph gives an exceedingly complicated tracing in the general direction northwest and southeast. The maximum possible displacement of the pendulum bob was 4·0 mm. in the direction indicated above.

At right angles to this the maximum displacement was 1·4 mm. The tracing is folded on itself from nine to eleven times.

MILLS COLLEGE, about 3:39 a. m.—The tracing from the duplex seismograph indicates motion in every possible azimuth. There is no marked tendency in any one direction. The maximum excursion of the pendulum bob is 11·1 mm. running from north northeast to south-southwest. By maximum excursion is here meant the maximum diameter of the diagram.

The tracing is such as might have been produced by "resonance," the amplitude increasing as the earthquake proceeded.

BERKELEY, 3:38 a. m. (Prof. Soulé).—The tracing from duplex seismograph gives maximum displacement (6·4 mm.) in a direction northeast and southwest.

There is quite a well-marked displacement of 4·3 mm. in an azimuth which may be defined as "west-northwest" to "east-southeast." The tracing recrosses itself from fifteen to twenty times. The disturbance at Berkeley seems to have been considerably smaller than at Mills College.

CHABOT OBSERVATORY, 3:37:44 a. m.—Duration six seconds; preceded by a rumble lasting ten to fifteen seconds. General character and size of tracing from duplex seismograph about the same as that observed at Berkeley. Maximum double amplitude of pendulum bob nearly east and west, amounting to 5·7 mm. (Mr. Burckhalter).

Digitized by Google

EAST OAKLAND, 3:37:40 a. m.—Mr. F. G. Bliun reports the duration at ten seconds and the intensity as IV (R F).

The seismograph tracing is exceedingly complicated, recrossing itself probably fifty times. The maximum displacement is east and west.

SAN FRANCISCO.—Following is the report of Prof. Davidson, as given by the Examiner: "(1) First shock light, but awakened observer 3:36:18 P. S. T. Direction, east and west. (2) Continuous shock 3:37:03 to 3:37:23; first part slight; last 'shock like a terrier-dog worrying a rat.' Trace east and west and north and south, giving resultant northeast and southwest or northwest and southeast, according to circumstances. Shock rang doorbell in Davidson's room. Stopped clock in room 39, Appraisers' Building. Recorded by Frank Edmonds as northwest and southeast."

The following from the Evening Bulletin gives observations in other parts of the state:

"SALINAS, April 24.—The heaviest temblor ever known here occurred at 3:40 this morning. Two light shocks were followed by a third and heavier, which lasted about twelve seconds. These were followed by four or five more, one of which was sharp and abrupt. The vibration was from east to west. Clocks were stopped, but no damage was done.

"BENICIA, April 24.—The people were awakened from slumber this morning at 3:45 by a very distinct shock of earthquake. The vibrations lasted some seconds and seemed to be from east to west.

"LOS GATOS, April 24.—Two distinct and severe earthquake shocks were felt this morning about 3:40, the last shock being much heavier that the first and of longer duration. The vibrations were from east to west. No damage was done, but many persons were considerably frightened and a few clocks were stopped. A slight shock was also felt about 5:30, but it was scarcely noticeable.

"BRENTWOOD, April 24.—A slight shock of an earthquake at 3:30 this morning.

"GILROY, April 24.—The damage by the earthquake this morning was not great. The gas mains were disjointed and the lights extinguished.

"SAN JOSE, April 24.—The shock of earthquake this morning was very sharp, but no damage is reported. Many people were frightened out of their beds.

"HOLLISTER, April 24.—Temblors began here at 3:32 a. m., lasting until 5:30 a. m. Thirteen distinct shocks were felt, and during the entire two hours a continuous vacillating motion was observable. The shocks were not sharp, but long continued and heavy rolling, the worst that have ever been experienced here. Only nominal damage was done. A private dispatch states that the McMahan House was twisted so badly that cracks were opened in it sufficiently large to admit a man's hand and that other damage was done.

Digitized by Google

"REDWOOD CITY, April 24.—Three shocks of earthquake occurred this morning, ending with a severe jar, which threw crockery and other articles from the shelves of several residences. Clocks were stopped at 3:37, the hour of the occurrence. The vibrations were east and west and the duration twenty seconds. The residents assert these were the severest shocks since 1868.

"POINT REYES, April 24.—A sharp shock of earthquake occurred here very early this morning.

"CENTERVILLE, April 24.—A heavy earthquake shock was felt here at 3:40 this morning. It was preceded by two light shocks. Many were frightened, but no damage has been reported.

"WATSONVILLE, April 24.—There were twelve distinct shocks of earthquake felt here after 3:30 this morning, the first and second being the most severe. The vibrations were from west to east. In the country north of town nearly all the chimneys were thrown down. The railway bridge across the Pajaro was misplaced and the train delayed.

"NAPA, April 24.—At 3:40 o'clock this morning a heavy shock of earthquake was experienced here. The vibrations were north and south.

"SANTA CRUZ, April 24.—There was a heavy earthquake shock this morning at 3:48, but very little damage.

"MAYFIELD, Cal., April 24.—A slight shock of earthquake was felt here and in neighboring towns this morning. The vibrations were from northeast to southwest, and lasted eight seconds. There was a heavy atmosphere, with no wind. The tops of trees rocked, making a noise like a heavy wind blowing. Plastering was broken and the depot clock and others stopped at 3:37 o'clock. The temperature was 48°. Superintendent Bassett and Assistant Superintendent Haydock went south by a special train to look after the damage done to the track by the shake between Pajaro and Sargents. It is reported that the track was moved a foot out of line, and that the ground settled six inches in places. The bridge, fifty feet high, is impassable at both ends, the rails being pulled a foot apart. A large force of men is at work, and they expect to have the track so that trains can pass in a few hours. At Sargents and Gilroy there were more than a dozen shakes, and chimneys were knocked down."

CARSON CITY, NEVADA.—No time reported. The duplex seismograph indicates a disturbance about one-quarter as large as that at Berkeley. (C. W. Friend.)

SAN JOSE, 3:37:43 a. m.—Seismograph at the University of the Pacific furnishes a diagram having a maximum double amplitude of 16·2 mm; from the manner in which the index has run all over the glass one would think the equilibrium of the pendulum too nearly neutral.

May 11.—EAST OAKLAND, 1:00:15 p. m. (Mr. Ireland); 1:00:18 p. m. (Mr. Boise).—Mr. Blinn's seismograph makes the disturbance almost entirely in an east and west direction; its amount (maximum double amplitude) was 1·0 mm. The diagram which Prof. Keep sends from Mills

Digitized by Google

College indicates a slightly smaller disturbance in a direction southwest and northeast.

SAN FRANCISCO, 1:00:15 p. m. (Mr. William Ireland).—Intensity= IV, Rossi-Forel scale.

Following is a newspaper account of the shock as felt at San Leandro May 11: "A very heavy shock of earthquake was felt at this place at 1:03 o'clock this afternoon. The oscillations were north and south and the duration 5 or 6 seconds. No damage reported, although many of the older houses in town were loosened up considerably, notably the depot of the Southern Pacific Company."

May 14.—SANTA CRUZ—The following general account is taken from the newspaper of even date:

"SANTA CRUZ, May 14.—Ever since the big earthquake of the 24th of April there have been daily seismic disturbances along the line between Pajaro and San Juan, where the earthquake was heaviest. Each day three or four small shocks occur, and yesterday six quite pronounced ones were felt. Two were felt at 5 o'clock this morning in this city. The fissure made on the Chittenden ranch, above Pajaro, during the big earthquake has been gradually increasing in depth and width. The railroad company is keeping a force of carpenters in the vicinity of the bridges between Pajaro and Gilroy for fear of damage by the shocks if they get heavier. It is said that there will be no change of the time card on the coast division until the earthquakes cease, as the company does not want to put on the Monterey flyer for fear of accident."

June 1.—HEALDSBURG, 1:21 p. m.—Slight shock.

June 29.—SANTA ROSA, 7:25 a. m. (newspaper).—"Three distinct shocks; people awakened; vibrations from north to south."

June 30.—Our information of this earthquake is comprised in the following three dispatches found in the newspapers:

"PETALUMA, June 30.—An earthquake shock passed through this city yesterday morning about 6 o'clock. The vibrations were from east to west."

"SANTA ROSA, June 30.—Three earthquake shocks were felt here about 11 o'clock. They were not quite as severe as those in the morning."

"SANTA CRUZ, June 30.—Earthquake shocks in this city at 12:30 this afternoon shook all the houses in town. The first shock was slight and was followed in a second by a much heavier shake. No damage was done. The vibrations were east and west. A private telegram from Sargent station, near the center of the seismic disturbance last April, states that the shock was quite severe there, breaking crockery in the houses."

July 1.—The following account appears to be from a San Francisco newspaper of even date:

"At 33 minutes past midnight of Monday there was a sharp shock of earthquake felt in this city, lasting ten seconds. The direction of the

Digitized by Google

vibrations was principally northwest and southeast, with a shock nearly north and south. It was felt in nearly all portions of the city and had the effect of rousing many people from their slumbers. Gas fixtures and windows were set rattling, and in some houses picture frames, loosely fastened on the walls, were thrown to the floors. It was not noticeable by people walking on the streets, and had no distinct violence in the down-town hotels."

GILROY, 12:35 a. m. (newspaper).—"Sharp shock from north to south lasting about one minute."

July 4.—EUREKA, 4:30 p. m. (newspaper).—"Quite a sharp shock."

July 24.—BAKERSFIELD, 3 a. m. (newspaper).—"Severe shock."

July 26.—The Examiner contains the following:

"SISSONS, July 26.—There were three earthquake shocks this morning at 1:45 o'clock. The vibrations were north and south."

"HYDESVILLE, July 26.—Several severe shocks of an earthquake were felt at this place at 1:40 a. m. to-day, lasting about twenty seconds, and another slight shock at 8 o'clock."

July 28.—PETALUMA, 12:03:35 a. m. (newspaper).—Two slight shocks from north to south.

August 17.—MILLS COLLEGE, 6:50 a. m. (Prof. Keep).—Slight, but distinct shock. The tracing of the seismograph shows three vibrations (averaging 0·3 mm.), in a direction from one point south of east to one point north of west.

August 23.—MONO LAKE.—The following is from the Homer Index:

"Remarkable earthquake at Mono.—The southern end of Mono Lake was considerably agitated last Sunday, and dwellers in that shaky locality were much perturbed. Steam was issuing from the lake as far as could be seen, in sudden puffs, and the water was boiling fiercely, like a bean pot, while high waves rolled upon the beach and receding left the sand smoking. In a moment the air was thick with blinding hot sulphurous vapor, and subterraneous moans and rumblings made the witness think that the devil was holding high carnival down below. The fences wabbled up and down and sideways; the wood pile at Nay's ranch locked arms with a big freight wagon and waltzed around the barnyard gleefully to the dismal bellowing of the dismayed cattle and the shrill neighing of terrified horses.

"This appalling fracas lasted about two minutes. Then came a blessed quiet for a moment, followed by a sudden twitch of the earth, as a horse jerks his hide and dislodges a bothersome fly. The shock threw men and animals off their feet with bruising violence, but it was the wind-up of the entertainment, which Mr. Nay hopes will not be soon repeated.

"It was some hours before the lake ceased to emit columns of steam and the water became very hot. Two springs near the house, long noted for the coldness and purity of their water, changed their character and spouted hot mud for two days, when they flowed cold water

Digitized by Google

again. A stack of 200 tons of hay was moved 70 feet south without disarranging it."

September 3.—MOUNT HAMILTON, 2:21:20 p. m. (accurate to one or two seconds), P. S. T.—Felt by Prof. Holden in third story of brick house and estimated by him at II on Rossi-Forel scale. Recorded on duplex seismometer, but did not start Ewing.

A slight shock was also felt at SAN FRANCISCO at 2:30 p. m.; likewise at GILROY.

September 4.—MOUNT HAMILTON, 10:06:45 a. m. (E. C. Holden).—"Swung the hanging lamp in my study."—E. S. Holden.

September 5.—MERCED, 2:15 p. m.—Vibration east and west.

September 19.—The record of earthquakes under this date consists of the following dispatches to San Francisco papers:

"CALICO, September 19.—A severe shock of earthquake occurred at 12:15 last night. There were vibrations east and west. There was another shock fifteen minutes later."

"DAGGETT, September 19.—Two earthquakes were felt here at 12:25 and 12:50 this morning. The vibrations were east and west. No damage was done."

"SAN BERNARDINO, September 19.—A light earthquake shock visited this city a little after 12 o'clock this morning."

"BARSTOW, CALIFORNIA, September 19.—There was an earthquake at 12:15 this morning, with a rumbling sound. No damage."

October 3.—HEALDSBURG, 12:05 p. m. (newspaper).—"Sharp shock, accompanied by long and distinct rumbling. Vibrations north and south."

October 29.—MOUNT HAMILTON.—Two distinct shocks.

First—8:36:29 a. m. ± 2s., P. S. T. Rossi-Forel, IV to V.

Second—8:39:29 a. m. ± 2s., P. S. T. Rosi-Forel, III. (Prof. Holden.)

Prof. Barnard reports as follows: "Coming to the observatory, halfway up the plank walk heard two distinct and heavy jars in the frame cottages as if they were falling down. These followed each other by about one or two seconds. *Did not feel any shock.* The noise of the shaking of the frame houses could have been heard perhaps an eighth of a mile. Reaching the observatory, another shock occurred; did not feel it; heard a rattling. This was at 8:39:35 ± one or two seconds, P. S. T.[1] I compared the clock in the earthquake instrument case with the Howard (this was for the first shock). Earthquake clock, 7:29:0; Howard 20:42:27."

December 4.—LONE PINE, 9 o'clock p. m. Ten distinct shocks felt from 9 to 11. No damage done. This was the seat of the great earthquake of March, 1872, in which many lives were lost.

"This is the first disturbance at Lone Pine for eight or ten years."—C. Mulholland.

Digitized by Google

CHRONOLOGICAL RECORD, 1891.

January 2.—Generally felt throughout the state.

Prof. Holden telegraphed from the Lick Observatory as follows:

"LICK OBERVATORY (Mount Hamilton), January 2.—A violent earthquake shock stopped our standard clock at eighteen seconds after noon to-day. The pendulum swings about north and south.

"Several ceilings were cracked in the observatory, and large pieces of plaster were thrown down in the brick houses. So far as I know no damage was done to the instruments. The earthquake registers indicate by far the severest shock since 1868 in northern California. Its intensity was VII on the Rossi-Forel scale. The pen of the duplex seismometer was thrown completely off the glass plate. Some definite idea of the force may be had when I say that a swinging lamp, making a pendulum of about 15 inches in length, which is suspended in my study, was still in vibration twenty minutes after the shock.

"Framed photographs on my mantel were overthrown. It appears that serious damage would be done to the houses here by a shock of twice this intensity, but it looks as if the observatory would stand considerably more. The large telescope has been secured to its base by four holding-down bolts, and it is as safe as it can be made."

Prof. Davidson's observation will be found among others reported below:

"San Francisco was visited by two distinct shocks of earthquake at noon yesterday (Jan. 2). Both shocks were distinct, but of a different movement, the first being vibratory, the second proving of the type known to seismic observers as undulatory.

"Prof. Davidson states that his chronograph recorded the time of the shock to be 12:00:40, with an entire duration of fifty seconds. A comparison of directions observed by various persons indicates the wave to have moved from southeast to northwest. In the lower portion of the city, from Kearny street to the water front, the shocks are said to have resembled the rumbling of a wagon, while in the more elevated residences the vibratory movement was perceptibly felt.

"SANTA CRUZ, January 2.—There was a heavy earthquake here at 12:02 this afternoon. The shock, which passed from southwest to northeast, lasted ten seconds, and was the heaviest felt here in years. Only very slight damage was done, but the people were greatly frightened.

"SALINAS, January 2.—A very severe shock of earthquake was felt here at 12 o'clock noon to-day. The vibrations were from north to south.

"EL VERANO, January 2.—A severe shock of earthquake was felt here to-day at 12:20 o'clock. It moved from southeast to northwest. Houses were shaken up.

"LOS GATOS, January 2.—A sharp shock of earthquake was preceded by a rumbling sound at 12:01 o'clock this afternoon. The duration of the shock was fifteen seconds. No damage.

Digitized by Google

"GILROY, January 2.—One of the heaviest earthquakes ever felt here occurred at 12:01 this afternoon. The duration was less than half a minute, but it was accompanied by heavy rumblings and a sickening, swaying sensation. Gas fixtures and movables swayed and clattered considerably.

"STOCKTON, January 2.—Rather a sharp shock of earthquake was felt here precisely at 12 noon. The vibrations were south to north.

"LATHROP, January 2.—There was a severe shock of earthquake at 12 o'clock to-day. Houses squeaked, clocks stopped, lamp chimneys were broken, etc. No further damage was done. Apparently the direction of the shock was from east to west.

"MODESTO, January 2.—A sharp earthquake shock was felt here at noon to-day. The shock lasted fifteen seconds. The vibrations were north and south.

"SAN JOSE, January 2.—At 12 o'clock a sharp earthquake shock was felt here, the movement being north and south, and it lasted about fifteen seconds. Clocks were stopped and buildings rocked, but no damage was reported.

"PETALUMA, January 2.—This afternoon, a few minutes past 12, a sharp shock of earthquake passed through Petaluma, with vibrations from east to west.

"SAN LEANDRO, January 2.—A sharp earthquake shock was felt here to-day at 12:02. The oscillations were from northeast to southwest. The duration was about ten seconds.

"SAN RAFAEL, January 2.—A rather sharp earthquake shock was felt here at 12 noon to-day, lasting several seconds. The vibrations were from east to west.

"BOULDER CREEK, January 2.—A severe shock of earthquake was felt here at 12 o'clock, continuing for several seconds. The vibration was from southwest to northeast. There was a general rush for the streets, but no damage was done.

"SPANISHTOWN, January 2.—A severe shock of earthquake occurred three minutes before noon to-day. The vibrations were from east to west.

"MERCED, January 2.—A slight shock of earthquake was felt here at 12 o'clock to-day with vibrations from east to west. The shake was heavy enough to cause the glassware on the shelves to rattle.

"REDWOOD CITY, January 2.—Two sharp shocks of earthquake were felt here to-day at two minutes past noon. The vibrations were east and west."—San Francisco Examiner.

"SAN JOSE, January 2.—"Buildings shaken so that their motion was plainly visible. Many clocks stopped at 12:00:30 p. m."—San Jose Herald.

Seismographic records obtained at Mills College by Prof. Keep and at Oakland by Mr. Blinn show the greatest disturbance to be in a direction running from northeast to southwest.

Digitized by Google

Mr. Blinn's seismometer gives a diagram indicating that the maximum double amplitude of the pendulum was 3·8 mm. The diagram consists of many (not less than 25) intersecting loops. So far as one may judge from the tracing, the instrument was in good adjustment.

Prof. Keep's tracing is of the same general character, but with a maximum double amplitude of 5·8 mm.

These maximum double amplitudes probably indicate very little in a diagram of this kind, in which the pendulum makes so many vibrations; for one can not tell to what extent it is a "resonance" phenomenon.

The Carson City seismometer (C. W. Friend) gives a tracing even more complicated than either of the preceding; it is the smallest of the three, but every azimuth is filled with fine lines.

The glass plate of the San Jose instrument was jarred by the earthquake and the record spoiled.

A third shock of intensity III on Rossi-Forel scale is reported by Prof. Holden as occurring at the Lick Observatory at 8:18:21 p. m.

January 12.—BERKELEY, 1:36 a. m.—Prof. Hilgard reports a "light earth-tremor lasting a little less than a second, but preceded by a marked rumbling from the southwest."

January 13.—MOUNT HAMILTON, 2:58 p. m., I to II Rossi-Forel scale; observed by Mrs. Breseno.

February 15.—DOWNIEVILLE.—Quite a shock felt between 2 and 3 a. m.

January 21.—SAN FRANCISCO, 2:24:35⅛ p. m.—Artificial earthquake, caused by the explosion of 3,000 pounds of blasting powder, for the purpose of clearing away a hill in San Francisco.

But few rocks were scattered; the hill collapsed and the earth in the neighborhood showed deep crevices.

No distubance was observed on the San Jose seismograph, which was watched by Prof. George. Nor was any record obtained at Mount Hamilton, where it was looked for with mercury basins.[1]

February 24.—INDEPENDENCE, 3:10 a. m.—Reported by Mr. C. Mulholland as follows: "A strong earthquake shock. The tremor was preceded an instant by a rumbling sound. The motion appeared to be a little east of south to west of north, i. e., parallel to the Sierra Nevada Mountains. The house shook so that the pans and dishes rattled. A strong breeze from the south had been blowing all night, but at the time of the tremor there was a brief but complete lull; then the breeze set in as before."

April 4.—MOUNT HAMILTON, 4:30 a. m.—"A light, but prolonged shock from east to west," reported by Prof. Holden.

April 12.—MOUNT HAMILTON, 9:29 (?) 41.—"A sudden, slight earthquake of intensity II, Rossi-Forel scale," reported by Prof. Holden.

April 13.—HEALDSBURG.—A sharp shock at 11:40 p. m.

[1] Publications Astronomical Society of the Pacific, vol. III, page 132.

Digitized by Google

VISALIA.—Earthquake at 10:30 p. m. Vibrations from north to south.

May 8.—BERKELEY, 6:10 p. m.—Prof. Frank Soulé writes: "Very slight in San Francisco and Oakland, so much so that comparatively few people noticed it. The Ewing and Gray-Milne instruments, though in excellent order and very sensitive, were not set off. The duplex gave a small record indicating that the direction of the shock was from northwest to southeast. From individual accounts, I should rate it as II in the Rossi-Forel scale.

SAN RAFAEL, 6:08 p. m.—A heavy shock lasting about six seconds. The vibrations were from west to east.

May 19.—SUSANVILLE.—Seven shocks felt; two very heavy; time not reported.

May 20.—MILLS COLLEGE.—Prof. Keep writes: "An earthquake was felt here last night about 10 o'clock. The shock was slight, but was preceded by a peculiar sound which made me brace myself for a severe shock."

The seismographic record accompanying this letter shows the greatest disturbance to have been in a north and south direction.

June 22.—PASADENA AND SAN FERNANDO.—Slight shocks felt between 8 and 9 o'clock in the evening.

June 28.—SAN FRANCISCO, 3:02:45 a. m.—Reported in San Francisco Chronicle as follows: "A double shock of earthquake occurred early yesterday morning. It was not heavy, and was of such brief duration that not many of the citizens who were awake at the time could have noted it. F. W. Edmonds, the assistant in Prof. Davidson's observatory, was at work when the shock came and noted its features, afterward comparing his figures with those recorded by a small seismograph. The first shock began at 3:02:45, Pacific standard time, and ended five seconds later. The vibrations were east and west. Then at 3:03:05 there was another shock, so brief that the duration was not recorded. It was sharper than the first shake, but had the same motion.

"Prof. Davidson remarked to a Chronicle reporter yesterday that one night last week, while he was making observations for latitude, there was an almost imperceptible quake. He was reading the level of the instrument at the time and noticed that it was suddenly shaken, the bubble moving backward and forward several times in quick succession. The extremes of this motion as marked by the bubble were three or four millimeters apart. The vibrations were north and south."

MOUNT HAMILTON.—Waked sleepers, set hanging lamps in vibration, rattled windows, pictures, stoves, etc. Ewing seismograph clock did not start; components were therefore recorded as straight lines. The actual displacements of the earth were as follows: North and south = 0·24 inches; east and west = 0·39 inches; vertical = 0·15 inches.

Prof. Holden makes the time 3:02:08[1] ± 20s. P. S. T.

[1] The first time here given is probably wrong. E. S. H.

Digitized by Google

Mr. Campbell makes the time 3:02:36 ± 2s. P. S. T.

Mr. Schaeberle makes the time 3:02:35 (watch). P. S. T.

Intensity on Rossi-Forel scale, V.

MAYFIELD.—"A slight shock of earthquake was felt here at 3 o'clock this morning. It lasted four seconds. Trembling vibrations were followed by two shocks."—Telegram to San Francisco Chronicle.

June 29.—MOUNT HAMILTON, 8:06:31 ± 2 a. m. (W. W. Campbell: 8:06:32 (J. M. Schaeberle).—One quick shock lasting for less than half a second; Rossi-Forel I or II. "Recorded on duplex, but not on Ewing seismometer." No record of measured displacements.

July 13.—MONTEREY, 4:27 p. m.—A sharp shock with vibrations from southwest to northeast. Clocks were stopped and crockery thrown from the shelves.

July 17.—HOLLISTER, 1 a. m.—Quite a severe shock; no damage.

July 30.—LERDO, MEX., was the center of a very severe earthquake about 6 o'clock a. m. It appears to have caused a tidal wave of considerable height at the head of the Gulf of California. The country is so thinly and poorly settled that no damage was done. The reports of this earthquake are so indefinite and contradictory that we have really very little reliable information regarding what must have been at least a very widespread disturbance. One newspaper report from Yuma, Arizona, makes the direction of the shock from east to west. Among other curious freaks a number of salt springs are said to have been made fresh; but judging from later investigations made by a Chronicle reporter who visited the scene, no reliance is to be placed on any statement of this kind.

August 9.—MONTEREY, 9:41 a. m.—A heavy shock, causing buildings to rock. The vibration was from north to south.

September 12.—CEDAR CITY, UTAH, 8:48 p. m. (C. Mulholland).—"Shock heavy and accompanied by a sound like that of a heavily loaded wagon passing over a street paved with granite blocks. Its duration was brief, and there was but one shock."

September 16.—SALEM, OREGON, 8:30 p. m.—The shock was brief and distinct, and was followed by a wave-like motion lasting several seconds. It was felt in all large buildings; windows rattled.

September 21.—PORT ANGELES, WASH.—Reports differ as to time, some claiming that the shock occurred at 4:10 a. m., others at 5 a. m. It is possible there were two distinct shocks. The direction of vibration was from northwest to southeast. Many people were awakened from sleep. Houses trembled and chinaware rattled.

PORT TOWNSEND.—Shock felt shortly after 4 o'clock a. m. Dishes rattled and sleeping people were awakened.

September 22.—VICTORIA, B. C., 3:40 a. m.—Sharp shock felt all over city; lasted about seven seconds.

September 23.—HEALDSBURG, 1:30 p. m.—"Very severe and long-continued shock; one of the most severe ever felt in this vicinity."

Digitized by Google

October 2.—MOUNT HAMILTON.—Prof. Barnard reports as follows: "From one and one-half to two seconds' duration. A very decided shock. Gradually increased in intensity. 7:19:55 P. S. T. end of shock."

Prof. Holden gives the time as 7:19:55. Intensity II on Rossi-Forel scale. No record on seismometers.

October 11.—Felt generally over the central portion of the state. Following are the newspaper accounts:

"SAN FRANCISCO.—A slight earthquake shock was felt throughout the city last night. It seemed like the heavy, noisy rumble of a cart, and was perceptibly felt in every part of the town. Prof. Davidson was at work in his observatory when it occurred. He did not consider it severe enough to disturb him in his investigations, as the pier upon which his instrument is placed was not thrown out of level in the slightest degree. The earthquake lasted for thirteen seconds, beginning at twenty-seven minutes and thirty-two seconds after 10 o'clock and ending at twenty-seven minutes and forty-five seconds after 10 o'clock. An unusual feature of the shock was that it began light and gradually increased until it was greatest during the last three seconds. The direction was southeast to east southeast. Prof. Davidson had no means of ascertaining the velocity of the shock, but he did not consider it in any way severe."

Mr. Burckhalter reports from the Chabot Observatory that the mean time clock was stopped at 10:27:49 p. m. His seismograph shows the actual displacement of the earth to have been 2·5 mm. in an east and west direction.

"SUISUN, October 11.—At 10:29 o'clock to-night a heavy shock of earthquake shook up this quiet little city in a frightful manner. The shock lasted nearly half a minute. It was the heaviest earthquake known of here for years. The damage is slight, but the fright of the people was extreme.

"OAKLAND, October 11.—A sharp shock of earthquake was felt here last night at 10:26, the vibrations being from north to south. Windows were shaken, but no damage done.

"SACRAMENTO, October 11.—A pretty lively shock of earthquake, or a double shock, was felt here at 10:28 to-night, but it was not heavy enough to do any damage. Many persons did not feel it.

"SAN JOSE, October 11.—A slight shock of earthquake was felt here at 10:28 this evening. The movement was from northeast to southwest.

"WINTERS, CAL., October 12.—There was a heavy shock of earthquake here last night about 10:30 o'clock. It was heavy enough to wake people from a sound sleep. The vibrations were from east to west and lasted two or three seconds.

"FAIRFIELD, CAL., October 12.—There was a heavy shock of earth-

Digitized by Google

quake here last night at 10:30 p. m. and another at 4 a. m., but no serious damage was done.

"SPANISHTOWN, CAL., October 12.—Quite a heavy shock of earthquake was felt here at 9:29 last evening.

"SONOMA, October 12.—Sonoma and vicinity were visited last night at 10:28 o'clock by the severest earthquake ever felt in this section of the State. The people were shaken out of their beds, chimneys were demolished, windows broken, and the interior of almost every plastered house in the town shows effects of the shock, which lasted about eight seconds. The temblor was a series of vicious twisters. Pickett's residence and wine cellar at the outskirts of town were badly damaged, the interior of the house presenting a scene of desolation. On S. F. Ringstrom's farm a large chimney fell and went crashing through the roof to the floor below. Several chimneys in town were also overthrown, but fortunately no one has been injured. Reports from all over the valley show more or less damage. On the Polpula ranch, which contains a number of warm-water springs, the earthquake caused the water to gush forth in perfect torrents. The first shock of the evening was slight and felt at 9:15. Then came the heavy one, after which, at intervals of an hour or so, there were eight or ten other shocks. More or less damage was done to every building in Sonoma Valley. People are greatly excited and everybody is talking 'earthquake.'

"PETALUMA, October 12.—At twenty-five minutes past 10 last night the heaviest earthquake shock since 1868 passed through Petaluma. Door-bells were rung and some plastering badly cracked. The heavy shock was preceded a few minutes by a light one, and after it came six or seven other shocks, the last one being at 5 o'clock this morning. Many people were kept awake most of the night. The main shock lasted fully nine seconds.

"NAPA, October 12.—The heaviest earthquake shock ever felt here was experienced at 10:34 o'clock last night. The people rushed out into the streets greatly frightened, and the whole town was in commotion. The shock was especially heavy at the insane asylum, and the inmates were almost uncontrollable.

"The first shock came at 9:16, but it was light. At 10:29 came the heavy shock, which lasted forty-six seconds. It was a twisting motion from right to left. Some people fainted, and all were greatly exercised, but no fatalities are reported. Lighter shocks followed during the entire night. Some say there were twelve shakes, while others profess to have counted as high as seventeen. Some people remained in the street all night, and others did not sleep for fear of a repetition of the dread sensation. The damage will not be very heavy on any one building, but in the aggregate is considerable. Scores of chimneys are thrown down or turned three-fourths around. Many brick build-

Digitized by Google

ings are badly cracked, and the wall decorations in most of the fine houses are badly damaged, while nearly every house had some bric-a-brac and crockery destroyed. The insane asylum reports some damage to the walls and tower, but nothing serious.

"ST. HELENA, October 12.—The heaviest earthquake shock ever experienced here occurred at 10:30 o'clock last evening. Houses shook, crockery rattled, and clocks stopped. The vibrations appeared to be south to north, followed half an hour later by a light shock, and one also at 5 o'clock this morning.

"SANTA ROSA, October 12.—The severest earthquake shock felt here in four years occurred last night at 10:32 o'clock. The oscillations lasted forty-five seconds. A slight trembling was perceptible for three or four minutes.

"SAN RAFAEL, October 12.—The most severe earthquake experienced here for years was felt last night at 10:26 o'clock. The shock lasted about twelve seconds. It was preceded by a dull rumbling noise like a heavy wagon rolling over the pavement. Much excitement was caused, and saloons and business places open at the time were soon relieved of their patrons, everybody seeking refuge in the street. Two shocks of lesser power were felt this morning about 4 o'clock."

October 13.—MOUNT HAMILTON, 11:0:30 (Prof. Holden).—"Intensity II, Rossi-Forel scale."

Prof. Barnard reports as follows: "Three shocks of earthquake were felt in rapid succession. Interval between the individual shocks about one and a half seconds. The last of these three was the most severe. This occurred at 11:00:09 P. S. T. The shocks were simply quick jerks, and ought to have been powerful enough to wake a person from ordinary sleep."

MILLS COLLEGE, 10:28 p. m.—Prof. Keep sends a very complicated diagram from his seismograph, indicating disturbances in all directions. Maximum north and south = 3·0 mm.; maximum east and west = 4·0 mm.

The above figures are for the actual displacements of the earth.

October 14.—SAN FRANCISCO.—Felt in all parts of the city. Prof. Davidson says: "The last shake was similar to the one of the 11th instant in its wave-like vibrations. Its greatest force was during the first seven seconds, and its entire duration was ten seconds. Time of beginning, 4:33:23 o'clock. Direction of the vibration, north and south."

Following are newspaper accounts:

"NAPA, October 14.—The earth continues to tremble. Four shocks have been felt here this morning. At 4:30 a. m. the people were startled with quite a heavy shock, and several lighter ones have followed. The damage done by Sunday night's shock is much more than

Digitized by Google

was at first supposed and will amount to several thousand dollars. Many of the people here are so terrorized that they have hardly slept since Sunday evening, and the slightest shock now starts many into the streets."

"PETALUMA, CALIFORNIA, October 14.—Another lively earthquake shock passed through Petaluma this morning about 4:30 o'clock, and a much lighter one about 7. The vibrations were north to south."

"SUISUN, October 14.—Shortly after 4 o'clock this morning the people here were aroused from their slumbers by another sharp, severe shock of earthquake. It was not as severe as the first one that occurred on Sunday night."

"SAN RAFAEL, October 14.—Quite a severe earthquake shock was felt here this morning at 4:25 o'clock. The shock lasted about ten seconds. The vibrations were from west to east."

Prof. Keep reports that the seismograph at Mills College indicated an actual displacement of the earth in an east and west direction amounting to 1 mm.

October 27.—MOUNT HAMILTON, 6:35:43±1s. (Prof. Holden).—Intensity I or II on Rossi-Forel scale. Prof. Barnard reports this as "a decided shock," occurring at 6:35:44.

November 8.—ASHLAND, OREGON.—Following is the newspaper account: "The first time an earthquake shock has been felt in Ashland for years was last night about 8 o'clock, when a distinct shock, though light and lasting only a very few seconds, caused a general rattling of window panes in many buildings in town. Though the shock was not heavy enough to cause even timid people any alarm, many unused to such occurrences did not realize what the disturbance was at the time."

November 29.—SEATTLE.—At 3:21 o'clock this afternoon two shocks of earthquake, lasting about five seconds each, were felt here. No damage was done.

The direction of the vibrations was southeast to northwest. One building swayed so much that the elevator bumped against the side of the shaft and could not move until the shock was over. Lake Washington, on the east side of town, was lashed into a foam, and the water rolled on to the beach 2 feet above the mark of the highest water and 8 feet above the present stage.

Reports from Snohomish and Bellingham Bay towns say the shock was plainly felt there.

PORT TOWNSEND, November 29.—A distinct shock of earthquake was felt here at 3:14 this afternoon. The shock continued fully twenty seconds. Buildings shook, windows rattled, and many persons rushed out of their houses. There was no damage done.

TACOMA, November 29.—A slight earthquake was felt all over the city at 3:16 this afternoon. No damage was done. Dispatches say there was a severe shock but no damage done at Olympia.

Digitized by Google

MENDOCINO, November 29.—Two shocks of earthquake were felt last night at 10:45 o'clock, preceded by a rumbling noise. There were two-minute intervals.

December 16.—MOUNT HAMILTON, 8:28:12 a. m.—Prof. Schaeberle estimates the intensity at I on the Rossi-Forel scale.

December 21.—MOUNT HAMILTON, 6:15:41 ± p. m. (Prof. Holden).—Intensity II on Rossi-Forel scale.

December 29.—MOUNT HAMILTON, 3:26:56 ± 3s. a. m.—Intensity I to II on Rossi-Forel scale.

Digitized by Google

Digitized by Google

INDEX TO PLACES.

	Page.
shland	28
kersfield	18
rstow	19
nicia	15
rkeley	14, 22, 23
ulder Creek	21
ntwood	15
lico	19
rson City	16, 22
dar City	24
nterville	16
bot Observatory	12, 14
ton	13
ggett	19
wnieville	22
t Oakland	15, 16
Verano	20
eka	18
rfield	25
oy	14, 15, 18, 19, 21
ldsburg	17, 19, 22, 24
lister	15, 24
esville	18
pendence	22
rop	21
lo	24
Pine	19
Angeles	13
latos	15, 20
field	16, 24
locino	29
ed	19, 21
College	14, 18, 23, 27
sto	21
Lake	18
ercy	24
t Hamilton	12, 14, 19, 20, 22, 23, 24, 25, 27, 28, 29
	12, 16, 26, 27
Oakland	12, 14, 25
Pasadena	23
Petaluma	17, 18, 21, 26, 28
Point Reyes	16
Pomona	13
Port Angeles	24
Port Townsend	28
Redwood City	16, 21
Sacramento	25
St. Helena	27
Salem	24
Salinas	15, 20
San Bernardino	13, 19
San Diego	13
San Fernando	23
San Francisco	15, 17, 22, 25, 27
San Jose	12, 15, 16, 21, 25
San Leandro	21
San Pedro	13
San Rafael	21, 23, 27, 28
Santa Ana	13
Santa Barbara	12
Santa Cruz	16, 17, 20
Santa Rosa	17, 27
Seattle	28
Sissons	18
Sonoma	26
Spanishtown	21, 26
Stockton	21
Suisun	25, 28
Susanville	23
Tacoma	28
Tehachapi	13
Ukiah	14
Victoria	24
Visalia	23
Watsonville	16
Winters	25

Digitized by Google

Digitized by Google

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 96

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

THE

OLUME THERMODYNAMICS

OF

LIQUIDS

BY

CARL BARUS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Letter of transmittal	13
Preface	15
Chapter I. Method of obtaining and of measuring very high pressures	17
Introduction	17
The screw compressor	18
General method	18
Special devices	18
Steel screw	18
Barrel. Head	19
Barrel. Head, improved	19
Barrel. Body	20
Barrel. End with piezometer tube	20
Piezometer tube. Vapor bath	20
Method of filling	20
Case for protection	21
Vertical piezometer	21
Pressure measurement	22
Tait gauge. Adjustment	22
Tait gauge. Graduation	23
Tait gauge. Volume increase measured and computed	29
Direct reading, Bourdon gauge	30
Concluding remarks	31
Chapter II. The isometrics of liquids	33
Introduction	33
Apparatus	33
Constant volume tube	33
Manipulation	34
Method of filling	35
Vapor baths	36
Method of cooling piezometer	37
Method of temperature measurement	38
Method of pressure measurement	38
Preliminary results	38
Data for ether	38
Discussion	39
Definite results	40
Apparatus improved	40
Notation	41
Data for ether	41
Method of purifying	42
Observations for ether	42
Observations for alcohol	44
Observations for thymol, para-toluidine, and diphenylamine	45

Digitized by Google

Page

Chapter II. The isometrics of liquids—Continued.
Temperatures corrected
Behavior of the torsion galvanometer
Air thermometer comparisons. Apparatus
Air thermometer comparisons. Observations
Isometrics corrected as to temperature
Correction for the thermal and elastic volume changes of the glass tubes
Thermal expansion of glass
Compressibility of glass
Compressibility of the above liquids
Deductions
Curvature and slope of the isometrics
Final interpretation
Isometrics of solid glass
Conclusion
Chapter III. A comparison of the Bourdon, the Tait, and the Amagat high-pressure gauges
Historical
The earlier work
Amagat's manometer
Bourdon gauge
Discussion of results
Multiplying mechanism
Fraunhofer micrometer
Tait gauge
Summary
Chapter IV. The continuity of solid and liquid
Introductory
Scope of the work
Other methods tested
Advantages of the present method
Apparatus
Temperature
Pressure
The volume tube
Method of measurement
Constants of the tube
Volume of the charge
Correction for expansion and compressibility of envelopes
Resistance measurement
Calibration
Electrolytic resistance and temperature
Volume in terms of resistance
Pressure coefficient of the electrolyte
Results of the measurements
Arrangement of the tables
Solid isothermal, 63°
Liquid-solid isothermals, 80°
Liquid-solid isothermals, 90°
Liquid-solid isothermals, 100°
Liquid solid isothermals, 117°
Liquid-solid isothermals, 130°
Deductions
Graphic construction
Hysteresis

Digitized by Google

Chapter IV. The continuity of solid and liquid—Continued.
Deductions—Continued. Page.
James Thomson's double inflections 90
The characteristic specific volumes 91
Critical point 92
Solidifying points and melting points 93
Transitional point 94
Solubility and pressure 95
Conclusion 96

Digitized by Google

Digitized by Google

ILLUSTRATIONS.

		Page.
Plate	I. Screw compressor, with parts in place	18
	II. Diagram showing the isometrics of ether, alcohol, thymol, para-toluidine, and diphenylamine	58
	III. Tubular piezometer, with appurtenances	76
	IV. Fusion isothermals of naphthalene. First set	86
	V. Fusion isothermals of naphthalene. Second set	88
	VI. Fusion isothermals of naphthalene. Third set	90
	VII. Fusion isothermals of naphthalene. Fourth set	92
	VIII. Diagram showing the conditions of fusion and of solidification	94
Fig.	1. Chart showing the bow-shaped cycles obtained in the gauge comparisons	25
	2, 2*a*. Direct reading helical Bourdon gauge	29
	3. Chart showing the action of the helical Bourdon gauge	31
	4. Constant volume tube; longitudinal section	33
	5. Constant volume tube; diagram	34
	6. Method of fastening the terminals	35
	7. Vapor bath and piezometer tube; longitudinal section	37
	8. Isometrics of ether; preliminary results	40
	9. Sectional vapor bath, for comparing air thermometer and thermocouple	48
	10. Longitudinal elevation of one of the halves of vapor bath, showing the thermometers in place	49
	11. Comparison of the Amagat manometer and the Tait gauge	69
	12. "Piston libre," for high pressure	70
	13. Diagram of the volume tube	75

Digitized by Google

Digitized by Google

TABLES.

		Page.
Table 1.	Comparison of Tait gauge No. 0, and Bourdon gauge	24
2.	The same gauge comparisons after long use	24
3.	High pressure tests	24
4.	Comparison of large Bourdon gauge with Tait gauge No. 1	26
5.	Comparison of Tait gauges Nos. 1 and 4	27
6.	Calibrations of Tait gauges Nos. 1 and 4	28
7.	Comparison of Tait gauges Nos. 1 and 4	28
8.	Calibrations of Tait gauges Nos. 1 and 4	28
9.	Comparison of Bourdon gauge and the spiral gauge	31
10.	Isometrics of ether. Preliminary results	38
11.	Digest of these data	39
12.	Isometrics of ether. Observations	42
13.	Isometrics of alcohol. Observations	44
14.	Isometrics of thymol. Observations	45
15.	Isometrics of para-toluidine. Observations	45
16.	Isometrics of diphenylamine. Observations	46
17.	Constants of the torsion galvanometer and couple	47
18.	Comparison of thermocouple and air thermometer	50
19.	Data interpolated from the above	50
20.	Isometrics of ether. Temperatures corrected	51
21.	Isometrics of alcohol. Temperatures corrected	53
22.	Isometrics of thymol. Temperatures corrected	53
23.	Isometrics of para-toluidine. Temperatures corrected	54
24.	Isometrics of diphenylamine. Temperatures corrected	54
25.	Isometrics of solid glass	54
26.	Correction factors, being compressibilities at θ° and p atm	56
27.	Corrections for thermal and elastic volume changes of glass tubes	57
28.	Isometrics. Digest of probable results corrected	58
29.	Observed initial slopes of the isometrics	59
30.	Order of values for internal pressure	61
31.	Cyclic comparison of the Bourdon gauge with the Amagat manometer. Multiplying gear	64
32.	Cyclic comparison of the Bourden gauge with the Amagat manometer. Fraunhofer micrometer	65
33.	Cyclic comparison of the Tait gauge with the Amagat manometer	67
34.	Volumes per unit of length	80
35.	Temperature coefficients and pressure coefficients of concentrated zinc sulphate solution	81
36.	Relation of volume and resistance at different temperatures	82
37.	Pressure coefficients	82
38.	Isothermals of naphthalene at 63.5°	84
39.	Isothermals of naphthalene at 83°	85
40.	Isothermals of naphthalene at 90°	85
41.	Isothermals of naphthalene at 100°	86
42.	Isothermals of naphthalene at 117°	88
43.	Isothermals of naphthalene at 130°	88
44.	Volumes of solid and liquid at solidifying points varying with pressure	91
45.	Volumes of solid and liquid at melting points varying with pressure.	92
46.	Showing the relation of solidifying point and melting point with pressure. Naphthalene	94

Digitized by Google

Digitized by Google

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY, DIVISION OF CHEMISTRY AND PHYSICS,
Washington, D. C., September 5, 1891.

SIR: I transmit herewith a manuscript by Dr. Carl Barus upon work done in the Physical Laboratory of this division, entitled "The Volume Thermodynamics of Liquids." I recommend that it be published as a bulletin of the Survey.

Very respectfully,

F. W. CLARKE,
Chief Chemist.

Hon. J. W. POWELL,
Director.

Digitized by Google

Digitized by Google

PREFACE.

In the following chapters, I have commenced a serious study of the volume thermodynamics of liquids and solids. The work is, as yet, confined to volume, pressure, and temperature. Questions involving entropy and energy are also in active progress, but can not be included in the present bulletin.

Accordingly the first and third chapters describe the method of generating and measuring high pressure (i. e., pressures up to 2,000 or 3,000 atmospheres) in full. The second chapter treats of the isometrics of liquids, and it is found that they can be very nearly represented by straight lines (Levy, Ramsay, and Young). The fourth chapter finally traces the isothermals, as yet of but one substance; but the results are none the less noteworthy since they indicate the occurrence of a critical temperature solid-liquid, and show a probable method of coordinating the normal type of fusion with the ice type, in a continuous diagram. The far-reaching importance of hysteresis, as accompanying all changes of molecule, whether chemical or physical, whether induced by stress, magnetization, temperature, or the intervention of affinity, and whether observed electrically, mechanically, or chemically, etc., is emphasized.

The work as a whole is tributary to the geologic views of Mr. Clarence King, by whom the importance of a deeper insight into the volume changes of liquids and solids was pointed out.

C. B.

Digitized by Google

Digitized by Google

THE VOLUME THERMODYNAMICS OF LIQUIDS.

By Carl Barus.

CHAPTER I.

METHOD OF OBTAINING AND OF MEASURING VERY HIGH PRESSURES.

INTRODUCTION.

1. Andrews's screw compressor has this advantage that the strains are all brought to bear within the compass of the barrel. In other arrangements, such for instance in which a cylindrical plunger is forced into the barrel, stress must be exerted on the bed plate or applied in a way tending to flexure of the plunger. It seemed to me, therefore, that the screw compressor might well be taken as a model for an apparatus of greater strength and efficiency than was necessary in Andrews's work. Indeed, Andrews himself seems to have been of this opinion,[1] and toward the close of his life devised an apparatus in which screw plungers are an essential part. Hannay and Hogarth,[2] however, were the first to carry a practical improvement of the screw into execution. They reached pressures but slightly short of 900 atmospheres, stating that their reasons for stopping work at this datum are quite apart from the efficiency of their apparatus. With the screw compressor[3] described below I obtain 2,000 atmospheres with facility (§ 17, 23). It is so constructed that a considerable volume of liquid can be operated upon, admitting of compressions of bulk of 5 cubic inches. Finally, special provision is made for the insulation of parts, thus enabling the operator to apply the essential electric methods in studying his test samples.[4]

Particular notice should here be given of the remarkable modification of Desgoffe's differential manometer, by which Amagat[5] succeeded

ERRATUM.

In § 74 there is a wrong entry of volume. The effect is such a shifting of the coordinate axes that 0·5016 cm³ must be added to all the subsequent volumes to correct the results. More rigorously an additional 0·000,011 cm³ per degree centigrade is to be added, and 0·000,001,32 cm³ per atmosphere deducted. The relations are therefore practically unchanged, and hence the inferences are sustained throughout.

Digitized by Google

pressure, but whereas on the one hand Amagat has as yet given only a meager account of his machine, Prof. Tait on the other has so recently described an apparatus on the principle of the "manomètre à pistons libres," that it seems expedient to refer the reader to Prof. Tait's memoir.[1]

THE SCREW COMPRESSOR.

2. *General method.*—The apparatus consists essentially of a strong wrought-iron barrel ABC_7, Pl. I, the head of which AA is suitably threaded, so that a steel screw $SSTT$ can be forced into it. The piezometer tubes are attached at the end CC of the barrel. Barrel and tubes are quite filled with oil.

3. *Special devices.*—It will facilitate comprehension if I state here at the outset the two chief devices used in the construction of the machine. The first of these is the *tinned* screw. This is an ordinary, well-cut machine screw of iron or steel, covered with a uniform thin adhesive layer of solder by dipping it in a vessel of the fused metal, soldering salts being used in the ordinary way. Screws of this kind, when forced into their sockets, secure complete freedom from leakage. Gauges and other appurtenances may thus be attached to the barrel or removed from it with convenience. The other device is the gasket of marine glue[2] or other very viscous liquid. A stuffing box is easily made, by which this substance is kept pressed against the threads of the screw, or against the smooth walls of a cylindrical plunger. The viscosity of marine glue is such that, whereas it easily admits of being shaped by pressure to fill up any cavity, the substance is yet far too viscous to flow through capillary interstices like those between the metallic parts of a well-fitting screw, except after the lapse of an enormous time (months). Thus I found the absolute viscosity of the glue to be 200×10^6. It would therefore require 1,000 atmospheres to force the cement through a capillary aperture .01^{cm} in diameter and 1^{cm} long, at the small rate of only .05^{cm} per hour, supposing (an unfavorable supposition) that its viscosity does not increase under pressure. For larger pressures the rate is proportionately increased. Now, it is the property of the above screw to close the apertures under pressure, since the metallic parts under these circumstances are bound more closely together. This probably further accounts for the insignificant leakage actually observed. I may note in passing that the viscosity of a pitchy substance like marine glue is therefore 20 billion times that of water.

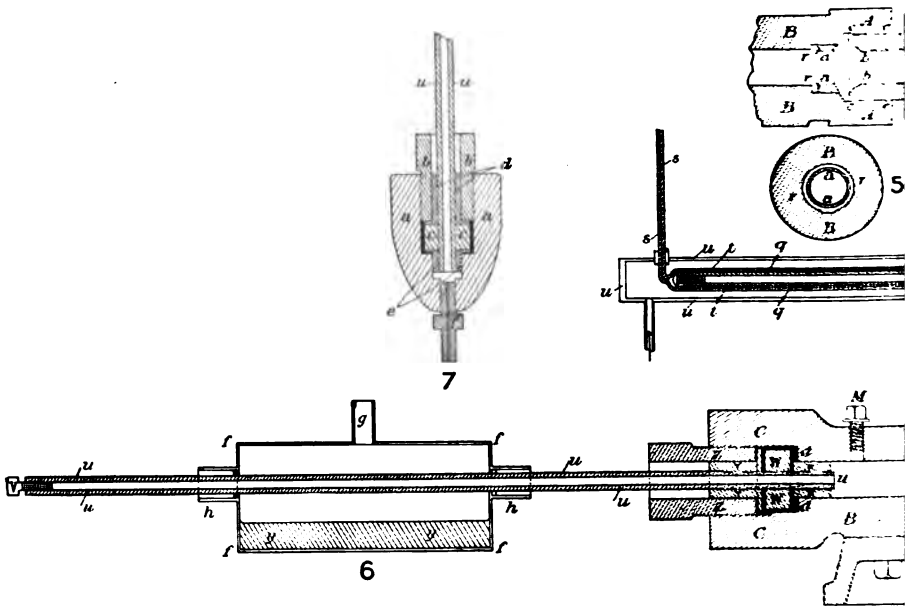
4. *Steel screw.*—To rotate the screw ST conveniently, it is provided with a lever and ratchet $LDRR$. The ratchet wheel is shown at RR in Pl. I, 1 and 3, and is cut so as to correspond with the right and left click D. A pin E, sliding in a socket of the lever L, and actuated

[1] Tait: *Challenger* Reports, 1873–'76, Physics and Chemistry, vol. 2. See Nature, vol. 41, p. 361, 1890.

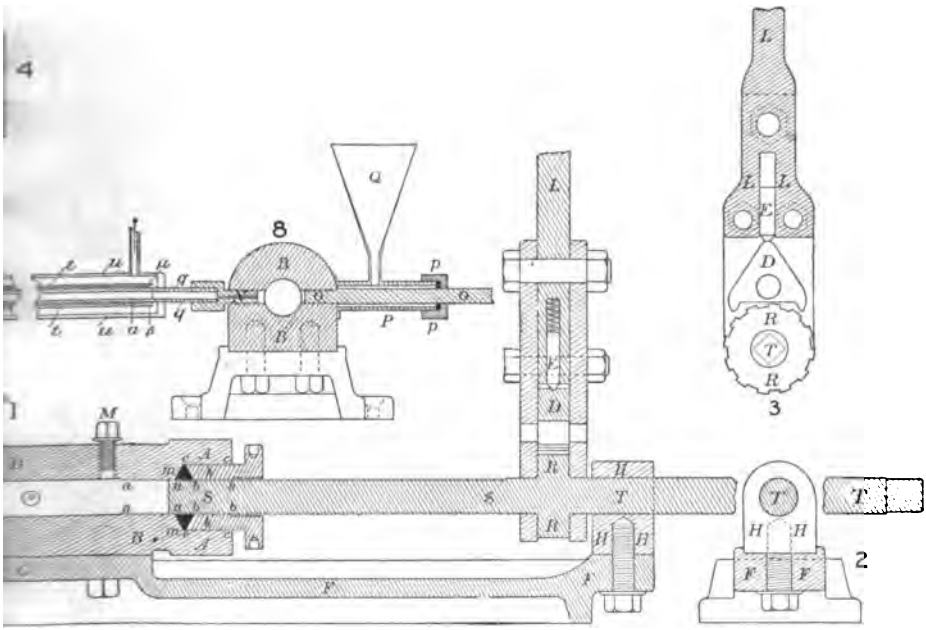
[2] Supplied by M. Ducretet, of Paris, or by the Société Genevoise. It is a specially prepared mixture of rubber and shellac. It may be thickened by adding shellac.

Digitized by Google

Digitized by Google

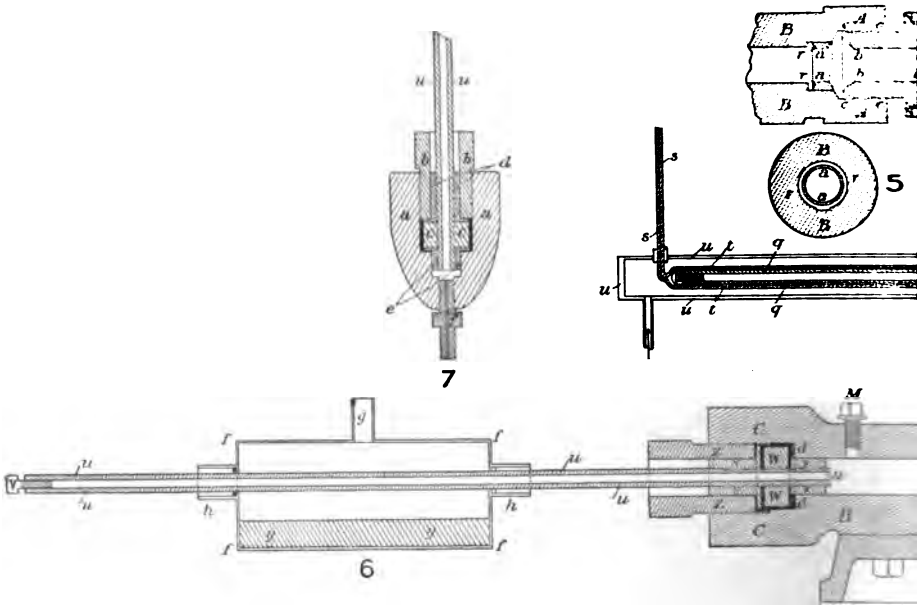


Digitized by Google



WITH PARTS IN PLACE,

Digitized by Google



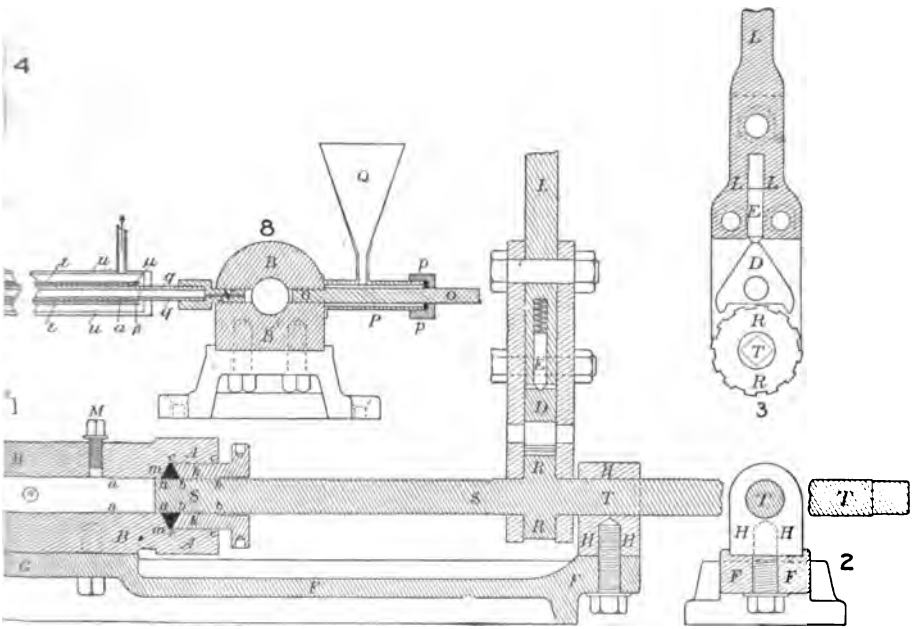
7

5

6

SCREW COMPRESSOR,

Digitized by Google



WITH PARTS IN PLACE,

Digitized by Google

Digitized by Google

by a spring, enables the operator to adjust the ratchet either for forward or retrograde motion of the screw *ST*, or wholly to withdraw the click from the ratchet, as shown in Pl. 1, 3. The figure gives a full account of the manner in which the parts of the lever and ratchet are put together. The ratchet wheel is securely forged to the screw. Essential parts are made of steel.

The screw *ST* is 1 inch in diameter. On the front half of it a thread of 12 turns to the inch is cut from the end to about 1 inch of the ratchet wheel. The rear half is a cylindrical shaft held in position by a journal *HHH*. The latter is bolted down to the bedplate *FG*, and additionally secured between slides, as shown in Pl. 1, 2.

5. *Barrel. Head.*—The planed front end of the cast-iron bedplate *FG*, the part *FF* of which is hollowed out so as to catch drippings, carries the barrel *BBB* already referred to. It is seen in cross-section in Pl. 1, 8, and its flat side is firmly secured to the plane of the bedplate by two bolts. The head *AA* of the barrel carries the stuffing box *kk*, of special construction. The efficiency of the screw depends entirely on this arrangement, and it must therefore be described in detail. *kk* is a hollow steel nut of the form shown, and provided with a large flange for screwing it in place. Both the inner and the outer cylindrical surfaces of the nut *kk* are threaded, with 12 turns to the inch. Moreover, the inner thread *bbbb* of *kk* is a continuation of the thread *aaaa* in the walls of the barrel. And since the thread *cccc* also has 12 turns to the inch, it is clear that the nut *kk* can be forced in or out of the head *AA*, no matter what the position of the screw *ST* may be. In practice *cccc* is cut first and the nut screwed in place. After this the whole thread *bbaaaabb* is cut at one time. To prevent leakage of the oil in the barrel through the threads of the screw, the gasket of marine englue *mm* is inserted and kept firmly pressed against the threads by the gland *kk*. At high pressure the friction is sufficient to hold the nuts in place, thus obviating the need of lock nut.

It is seen that after the screw enters the barrel the chief strain of compression is borne by the thread *aaaa*. The threads *cccc* and *bbbb* hold the material of the stuffing box forcibly in place.

6. *Barrel. Head, improved.*—There is an objection to this form of stuffing box, inasmuch as at very high pressures the threads *aaaa* and *bbbb* tend to act as lock nuts on each other. To obviate this annoyance I devised the method shown in Pl. 1, 4 and 5. Here the thread *aa* is movable, being on the inside of a ring *rr* of steel, which fits snugly in a socket of the barrel. The ring *rr*, though capable of moving back and forth, can not rotate, being prevented by a projection corresponding to a slot in the barrel. In this way the material in the stuffing box is not forced into the barrel on actuating *kk*. Note that the thread within *kk* is carried quite to the end, and that the inner face of *kk* is beveled very obliquely, thus allowing the gasket to encircle a greater number of threads of the screw *SS*. The strain is now borne by the thread *bb*. Experiment has shown this to be no disadvantage.

Digitized by Google

7. *Barrel. Body.*—This is perforated by four or more holes (Pl. 1, 1) about three-eighths of an inch in diameter, and threaded to admit the tinned machine screws. Two of these *MM* are vertical, the other two *N*, *O* (Pl. 1, 8), horizontal. They are of use in filling the barrel with oil, for attaching gauges and other appurtenances.

8. *Barrel. End with piezometer tube.*[1]—The steel tube *uuu* is inserted in such a way as to insulate it electrically from the barrel end *CC*. A screw is cut on the end of *uuu*, fitting into a cast-iron flange *WW* between two cylindrical jackets *XX* and *YY* of hard rubber or ivory. These parts *Y*, *W*, *X* are screwed to the end of the tube *U*, and the cylinders *Y* and *X* are turned large enough to fit the hole of the barrel and the internal aperture of the steel gland *ZZ* snugly. All space within the head *CC* is filled with marine glue *dd*. This is easily accomplished by melting the cement into the crevices between *Y* and *W*, *W* and *X*, before putting the piezometer in place. A thick gasket *dd* is also inserted. After this the remaining annular space around *W*, through which leakage might occur, is filled by forcing in the nut *ZZ* gradually, and at a temperature not too low.[2] To obviate possible electric contact between *W* and *Z*, the rubber jacket *Y* is flanged.

9. *Piezometer tube. Vapor bath.*—The further end of the piezometer *uu* is closed with a tinned screw *V*. The substance to be examined is inserted in ways which must be specially described for each experiment. As a rule the same tubes are adjusted within the compass of a copper vapor bath *ffff*, Pl. 1, 6. This is a hollow cylinder, closed at both ends, through which a suitable thin copper tube *hh* passes somewhat above the middle and from end to end. The liquid *yy* to be boiled is introduced into *ffff* and heated with a large burner. The vapors escaping at *g* are condensed and run back, thus making the ebullition continuous. A number of baths of this kind are at hand, each containing a substance of suitable boiling point. In order to pass from one temperature to another it is merely necessary to slip off one vapor bath *ff* and slide on another. The copper vessels are to be surrounded with thick asbestos jackets in the usual way, and proper provision made to close up the ends of the tube *hh* so that convection currents may be obviated.

10. *Method of filling.*—When the screw is in good adjustment leakages are small and fresh supplies of oil are not frequently necessary. A convenient method of filling the screw with oil is indicated in Pl. 1, 8. The steel rod *oo*, threaded at one end and provided with a strong cross

[1] Weldless cold-drawn steel tubing of any dimension may be obtained from John S. Leng, New York, or of Philip S. Justice, Philadelphia, Pennsylvania. Both gentlemen are agents of English houses whose address is not known to me.

[2] The figure is somewhat diagrammatic here to exhibit the parts. In practice I use hard-rubber cylinders *XX* and *YY*, and two hard-rubber annular disks between *YY* and *WW* and *WW* and *XX*, respectively. When ready for insertion, the cylinders are screwed against *WW*, so that there are mere films of marine glue left between contiguous planes. Finally, the nut *ZZ* is brought in contact with the flange *YY* (disk) by pressure. It is in view of the fact that *YY* is pressed radially inward toward the axis of *UU*, as well as outward by pressure, that the arrangement holds so well. Repacking is only rarely necessary.

Digitized by Google

handle at the other, is surrounded by a cylindrical tube of brass *P* surmounted by a funnel-shaped inlet *Q*. Both *Q* and *P* are kept full of oil, and to prevent leakage there is an ordinary stuffing box at *pp*. A spring clamp (not shown in the figure) keeps the end of the tube *P* of the filler *PQ* appressed against the barrel *BB*, a leather washer being suitably interposed. To manipulate the filling arrangement, the pressure is taken off and *oo* screwed out without removing it from *P*. The oil in *PQ* will then follow the retreating screw *ST*, Pl. I, 1. To fill the barrel completely, one of the screws *M* may be removed until oil exudes. It is clearly advisable to remove all the air out of the barrel and piezometer tubes, otherwise *ST* must be forced in to a considerable part of its length before the air-spaces are sufficiently compressed to sustain high pressure. Ordinary sperm oil or machine oil of a thickish quality, yet sufficiently thin to flow, is available for filling the barrel. It has a great advantage over water in not rusting the barrel, and in keeping the moving parts oiled. Mercury is objectionable, since it would dissolve the tin coating on the bolts, and thus soon produce leakage.

11. *Case for protection.*—Working as far as 2,000 atmospheres, explosions are not infrequent. They occur with slight detonation, scattering thin mists of oil. But there has been nothing of a serious nature. It is necessary, however, to surround the barrel with a case of 2-inch plank, and to put a barricade beyond the end of the piezometer tube. A tin pan, suitably fastened below the bed plate of the screw, is advantageous in catching oil. After filtering this may at once be used over again.

12. *Vertical piezometer.*—An adjustment similar to *CC uu*, but smaller in dimensions, and ending below in a finely perforated screw, may be attached at *M*. The piezometer is thus fixed in vertical position, and is easily adjusted or withdrawn, while the end of the barrel is available for other purposes. (§ 23.) A full view of the vertical piezometer is given in Pl. I, 7, and Pl. III, below, shows the same, with appurtenances.

In Pl. I, 7 *aa* is a hollow pear-shaped piece of steel, which can be attached to the barrel by means of the perforated tinned screw *f*. The piezometer tube of steel is shown at *uu*, and is provided with a steel flange piece *cc*. The hard rubber flanges for insulation are screwed on at *d* and *e*, and the system held in place in a medium of marine glue, by the steel gland *bb*. The advantage of the vertical adjustment lies in the fact that a surface of separation or meniscus of mercury is very much less apt to be broken in the vertical position of the column than is any other. It is also frequently desirable to produce gravitational separation of mixed liquids under pressure. Finally, since the apparatus Pl. I, 7 is complete in itself, the electrical and other adjustments may be made, and all glass apparatus within *uu* fastened before the piezometer is screwed into the barrel. Note that the tube *uu* and the barrel are insulated from each other.

Digitized by Google

PRESSURE MEASUREMENT.

13. *Tait gauge. Adjustment.*—The gauge connects at *N*, Pl. 1, 8, and is shown at *qq*, *tt*, *ss*. The essential part is the steel tube *qq*, closed at one end by the tinned bolt *r*, and connecting at the other with the reducing piece *N*. I added *N* because it is not advisable to cut a deep thread in the tube *qq*. Connection may be made with *N* by a shallow fine thread and solder, and the connecting thread cut in the thick-walled tube of *N*. The tube *qq* is filled with oil. To measure the expansion of *qq* under pressure it is surrounded by a close-fitting glass tube *tttt*, one end of which is joined to the steel tube at $\mu\alpha\beta$ by a layer of marine glue. The other end of *tt* communicates with the vertical capillary tube *ss*, by which the expansions are measured.

It is clear that the shell-like space between the steel tube *qq* and the glass envelope *tt* must be filled with a liquid of small coefficient of expansion. I first tried mercury, but found it almost impossible to fill *tt* in such a way as to entirely exclude air. Moreover, in view of the friction of the mercury thread in *ss*, any trace of air in *tt* will produce irregular motion, and vitiate the experiment. Colored alcohol shows too much thermal expansion. I therefore used water colored with an alcoholic solution of fuchsine. Under these circumstances a sufficient constancy of temperature may be obtained by surrounding *tt* with a jacket *uu* of circulating cold water coming directly from the hydrant. Thus the temperature error may be reduced so as not to exceed 10 atmospheres, reasonably slow motion of the screw presupposed. (See below.) To keep the liquid in *ss* at a given fiducial mark, a special adjustment for moving the meniscus suggests itself; but this is an exceedingly difficult device to apply, seeing that there must be the minimum of water in *tt*, and that obsolutely tight joints are essential. Hence I raise or lower the meniscus and color it, when faded, by inserting filimentary glass tubes into the canal of *ss*. Such tubes are easily made by drawing out a wide glass tube and then covering the open wide end with a rubber cap. Using such tubes there is little difficulty either in adding more liquid to the thread in *ss* or in withdrawing liquid from it.

It is advisable to protect the steel tube *qq* from rusting, either by nickel-plating it or in other ways. I observed, however, that water free from air and containing a little alcohol does not easily rust iron. After an exposure of several months, bright surfaces were still untarnished. A dilute solution of rubber may possibly be used for coating the tube. Thick coats are to be avoided, because they interfere with the expansion.

In later experiments I made the joint at the closed end of the glass envelope hermetic and rigid, as follows: In Pl. 1, 8 a is a layer of marine glue between steel and glass, and μ a plug of fusible metal, the whole being surrounded by an external close fitting copper envelope

Digitized by Google

(wired to the glass) β. The latter being a prolongation of the glass tube, the layers α and μ are melted in, while the gauge is held in a vertical position. The effective part of the steel tube qq is about 100^{cm} long, 1^{cm} thick externally, and ·5^{cm} in internal bore. A capillary tube of the rather wide bore ·07^{cm} is then sufficient for measurement, showing a displacement of meniscus of nearly 2^{cm} per 100 atmospheres pressure. Data are given more accurately below. My reasons for using a long tube are these: That the effective length can be more accurately stated. In short tubes the error at the joint $\mu\alpha$ is much more serious. Again, since the expansion corresponding to a given pressure increases in absolute magnitude with the length of qq, it is clear that a wider capillary tube at ss will suffice when qq is long. A wide capillary ss is obviously convenient, since it can be more easily adjusted for zero in the way just stated, and since the tube qq itself can be more easily filled by aid of the air pump. When the gauge is properly charged and adjusted, it must show no displacement of the fiducial zero during the interval of experiment.

In later experiments I bent the vertical tube ss, Pl. 1, 8, horizontally, so that its measuring parts lay close to uu and immediately above a millimeter scale. A somewhat finer capillary corresponding to about 2,000 atmospheres per meter was used with advantage. So constructed the Tait gauge[1] is very much more compact and less fragile.

14. *Tait gauge. Graduation.*—To graduate the gauge I compared it with a large Bourdon gauge, reading from 0 to 1000 atmosphere. The tube of the latter in this case communicates with the barrel through one of the screws *M*. This comparison with the Bourdon gauge is a check on both instruments, and the statistics are therefore given below. It affords no means of checking the correct value of the standard atmosphere employed. But since both gauges are based on Hooke's law, and provided with scales of equal parts, the relations are well indicated. In the table $2a_0$, $2a_1$, and L, denote the internal, the external diameters, and the length of the steel tube qq, Pl. 1, 8, 2ρ, is the bore of the capillary ss.

[1] The form of steel high pressure gauge based on Hooke's law recommended but not constructed by Prof. Tait (loc. cit.), is somewhat different from the above. I think my form has the practical advantage of greater simplicity, being essentially a single-walled tube. The method of computation is due to Prof. Tait. It was my purpose to make the tube tt of brass, so that the heat of compression would be more quickly dissipated. But I failed to obtain tubing of the proper bore and strength until quite recently.

Digitized by Google

TABLE 1.—*Comparison of Tait gauge No. 0, and Bourdon gauge.*

[$a_0 = .27^{cm}$; $a_1 = 1.00^{cm}$; $L = 100^{cm}$; $\rho = .034^{cm}$.]

Time =	15m	30m	45m	75m	90m
Bourdon.	Tait.	Tait.	Tait.	Tait.	Tait.
Atm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
0	1·90	2·10	2·00	2·18	2·16
100	3·58	3·70	3·60	3·85	.....
200	5·20	5·50	5·35	5·55	.....
300	7·05	7·25	7·20	7·45	7·30
400	8·70	9·00	8·90	9·10	.....
500	10·50	10·72	10·70	10·85	.....
600	*12·50	12·50	12·45	12·55	12·70
700	14·10	14·10	14·10	14·20	.....
800	15·65	15·70	15·70	15·85	.....
900	17·22	17·20	17·30	17·45	.....
1000	18·80	19·00	19·00	19·10	19·20
900	16·62	16·70	16·80	16·80	.....
800	14·65	14·70	14·63	14·70	.....
700	12·80	12·80	12·75	12·92	.....
600	10·95	11·00	11·00	11·12	11·00
500	9·30	9·28	9·23	9·35	.....
400	7·55	7·55	7·50	7·60	.....
300	5·95	6·00	6·10	6·15	5·85
200	4·50	4·55	4·60	4·60	.....
100	3·04	3·12	3·15	3·20	.....
0	1·74	1·90	1·90	2·00	1·60
Rate, in centimeters, per atmosphere...	=.0169	·0171	·0172	·0172	.....

* Break in the measurements.

15.—TABLE 2.—*The same gauge comparisons (No. 0 and Bourdon) after long use.*

Large Bourdon.	Tait.	Tait.	Factor.	Mean.	
100	6·35	6·27	·01715	·01722	.....
200	8·03	7·96	1725	.....	.....
300	9·79	9·70	1720	.....	.....
400	11·48	11·41	1728	.....	.....
500	13·26	13·16	.....	.....	.....

Small Bourdon.	Large Bourdon.	Tait.	Tait.	Factor.	Mean.
30	31	4·94	5·05	·01722	.01725
120	121	6·42	6·53	1767	.....
210	210	8·04	8·05	1667	.....
300	300	9·60	9·67	1744	.....

TABLE 3.—*High pressure tests.*

$P = 0$	$N_P = 4·90$	.....	.....	.....	.....
2110	40·93	.....	.....	.....	.....
0	5·10	.....	.....	.....	.....
2160	41·95	.....	.....	.....	.....
0	5·20	.....	.....	.....	.....

16.—Table 1 contains five series of observations made at the times stated. In the first four series I went up to the maximum and down again gradually, but not slowly. The last I operated as fast as the experiment would permit. To determine the degree of accuracy it is well to consult the rates at the bottom of the table. These show that a mean displacement of ·0171cm of the meniscus takes place in the pressure in-

Digitized by Google

creasing series for each atmosphere pressure. Consulting data on the same horizontal row it appears that the differences of reading of the new gauge corresponding to a given reading of the Bourdon gauge are greatest in the region of low pressures. At zero the maximum differ-

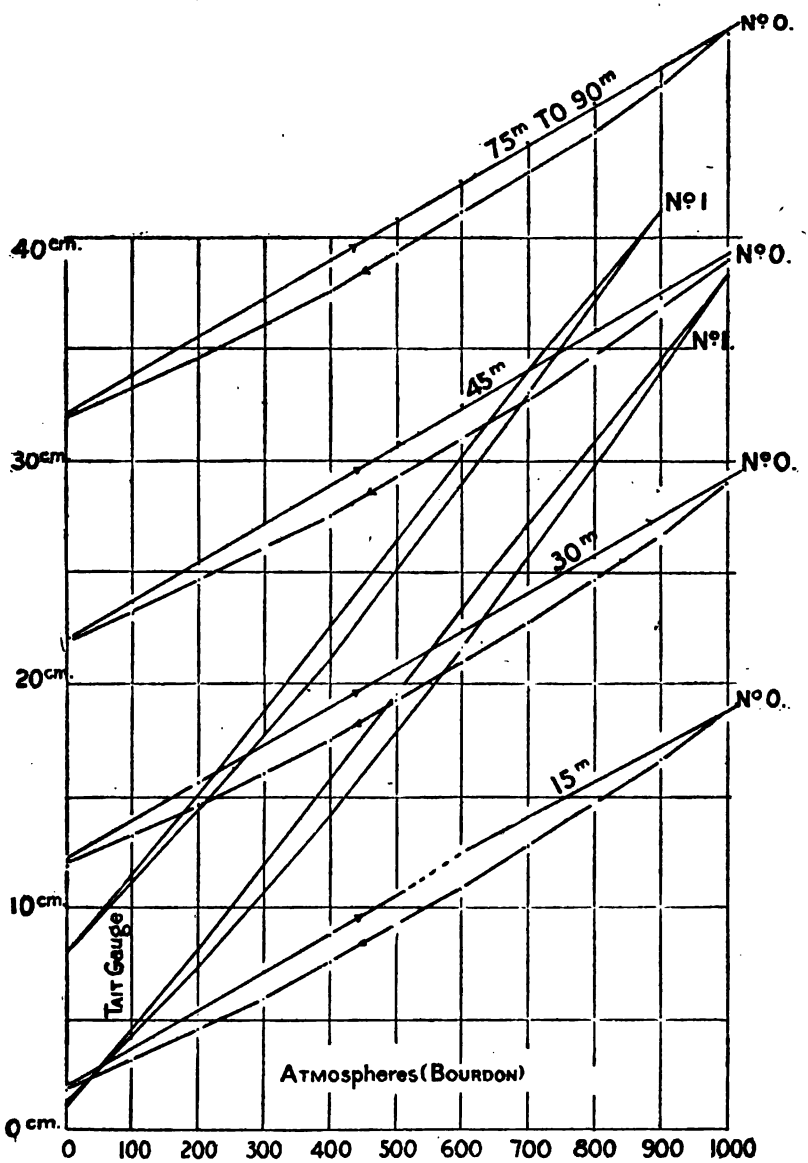


FIG. 1.—Chart showing the bow-shaped cycles obtained in the gauge comparisons.

ence observed is ·40cm, equivalent to an error of 24 atmospheres. Again, comparing the two zero readings of the last column, the difference of reading is ·56cm, corresponding to 33 atmospheres. This, therefore, is a maximum index of the inaccuracy of the Tait gauge due to thermal

Digitized by Google

effects of compression and unreasonably hasty work. To diminish this error further, it is necessary to decrease the bore of the glass tube *tt* in Pl. I, 8, thus making the thermometer property of the gauge of smaller importance. In the above apparatus this tube was 1·15^{cm} in internal diameter, corresponding therefore to a liquid interstratum ·07^{cm} thick. Clearly this admits of further reduction. A brass tube would in many respects be preferable to a glass tube, since in this case the heat of compression is more easily dissipated; but I did not find one of the necessary dimensions.

17.—A second point of view is obtained by comparing the data of the pressure "on" and of the pressure "off" phases of the above experiments. For convenience I insert the Chart, Fig. 1, in which the data of Table 1 are inserted. It is seen at once that the degree of accordance in the "on" series is satisfactory. The errors are nowhere larger than 10 atmospheres. The loci, apart for slight circumflexure, are straight lines. In the "off" series, however, this good uniformity is lost. The data lie on consecutive broken lines. The feature of particular importance is, however, this: The observation that the "off" data do not at all return on the lines of the "on" data. Indeed the two lines, "on" and "off," inclose a band the maximum width of which is even 1.5^{cm}, corresponding to 90 atmospheres. Since this band widens at once at 900 atmospheres, and falls off at zero atmosphere, it is clearly due to a *virtual* shifting of the fiducial zero of the mechanism of the Bourdon gauge.

In the present comparisons, therefore, the "on" series of data need alone be considered. It appears for these, slow work presupposed, that the error of the gauge in the above form need not exceed 10 atmospheres, and that it can certainly be reduced decidedly below this limit by diminishing the bore of the glass envelope *tt*, Pl. I, 8.

18.—TABLE 4.—*Comparison of large Bourdon gauge with Tait gauge No. 1.* $\rho = .0220^{cm}$. $a_1 = 1^{cm}$. $a_0 = .27^{cm}$.

Large Bourdon.	No. 1.	Diff.	Large Bourdon.	No. 1.	Diff.
Atm.	*Cm.*	*Cm.*	*Atm.*	*Cm.*	*Cm.*
0	17·18	.....	900	51·27	.....
100	21·30	3·49	800	47·12	4·15
200	25·03	3·73	700	43·10	4·02
300	28·85	3·82	600	39·11	4·00
400	32·63	3·78	500	35·12	3·99
500	36·50	3·87	400	31·32	3·80
600	40·35	3·85	300	27·75	3·57
700	44·05	3·70	200	24·31	3·44
800	47·55	3·50	100	21 00	3·31
900	51·25	3·70	0	17·96	3·04

Second comparison. Another thread length.

0	5·96	.....	1000	43·40	.....
100	9·42	3·46	900	39·00	4·40
200	13·17	3·75	800	34·75	4·25
300	17·00	3·83	700	30·76	4·00
400	20·74	3·74	600	26·75	4·01
500	24·66	3·86	500	22·84	3·91
600	28·45	3·85	400	19·13	3·71
700	32·15	3·70	300	15·74	3·39
800	35·78	3·63	200	12·36	3·38
900	39·57	3·79	100	9·14	3·22
1000	43·36	3·79	0	6·21	2·93

Digitized by Google

Third comparison. Large Bourbon gauge with Tait gauges Nos. 1 and 3.

[No. 1, $\rho = .0220^{cm}$. No. 3, $\rho = .0336^{cm}$.]

Large Bourdon.	No. 1.	No. 3.	Large Bourdon.	No. 1.	No. 3.
Atm.	*Cm.*	*Cm.*	*Atm.*	*Cm.*	*Cm.*
0	4·72	26·59	1000	43·20	43·28
100	8·29	28·17	900	38·93	41·36
200	12·03	29·81	800	34·58	39·55
300	15·85	31·50	700	30·75	37·87
400	19·48	33·11	600	26·65	36·13
500	23·40	34·82	500	22·68	34·49
600	27·32	36·59	400	19·03	33·00
700	31·04	38·23	300	15·62	31·63
800	34·68	39·81	200	12·24	30·24
900	38·53	41·53	100	8·95	28·86
1000	43·19	43·28	0	6·08	27·60

Cyclic comparisons.

0	6·10	27·92	0	5·98	28·92
100	9·55	29·45	100	9·43	30·50
200	13·27	31·15	200	13·20	32·19
300	17·12	32·64	300	17·05	33·87
400	20·94	34·51	400	20·94	35·51
300	17·13	32·90	500	24·75	37·17
200	13·30	31·29	600	29·00	38·89
100	9·52	29·77	700	32·63	40·39
0	6·08	28·64	800	36·44	42·00
0	6·08	28·64	900	40·18	43·57
100	9·60	30·10	1000	45·10	45·27
200	13·39	31·61	1000	45·13	45·28
300	17·19	33·27	900	40·72	43·43
400	20·96	34·86	800	36·50	41·63
500	24·83	36·54	700	32·49	39·97
600	28·40	38·12	600	28·49	38·35
700	32·30	39·74	500	24·57	36·74
600	28·39	38·07	400	20·86	35·.4
500	24·35	36·39	300	17·41	33·83
400	20·38	34·77	200	14·09	32·46
.....	Accident.		100	10·80	31·16
0	6·02	28·69	0	7·78	29·97

19.—TABLE 5.—*Comparison of Tait gauges Nos. 1 and 4.*

No. 1.	No. 4.	No. 1.	No. 4.	No. 1. atm.	No. 4. atm.
— ·35	10·38	New adjustment of No. 4.			
6·42	13·43				
13·10	16·43	1·39	10·78		
20·20	19·69	7·68	13·54		
30·08	24·09	14·45	16·60		
38·00	27·95	20·54	19·33		
31·49	24·71	28·40	22·85		
23·62	21·23	34·39	25·53		
16·96	18·02	40·07	28·07		
8·96	14·61	46·35	31·05		
1·35	11·22	52·75	34·49		
7·78	14·11	59·02	38·18		
15·67	17·66	63·75	41·62	1761	1783
21·41	20·37	63·53	41·25	1755	1760
28·54	23·56	63·11	41·11	1745	1750
35·31	26·48	56·44	38·26	1564	1579
40·00	28·67	47·36	33·96	1317	1320
32·65	25·35	40·98	31·32	1145	1161
25·86	22·39	33·61	28·10	947	967
19·84	19·69	26·95	25·11	766	787
13·38	16·69	19·24	21·63	557	577
6·25	13·55	13·05	18·80	389	407
·60	11·02	5·54	15·28	185	195
		1·25	12·05	00	00

Digitized by Google

TABLE 6.—*Calibrations of Tait gauges Nos. 1 and 4.*

No. 1.	No. 4.	Small Bourdon.	No. 1 factor.	No. 4 factor.
— 1·30	12·02	0	3·65	1·63
2·28	13·63	100	3·69	1·67
6·00	15·29	200	3·60	1·67
9·66	16·97	300	3·73	1·61
9·65	16·96	300		
5·90	15·26	200	3·69	1·66
2·20	13·62	100		
— 1·30	12.04	0		

TABLE 7.—*Comparison of Tait gauges Nos. 1 and 4.*

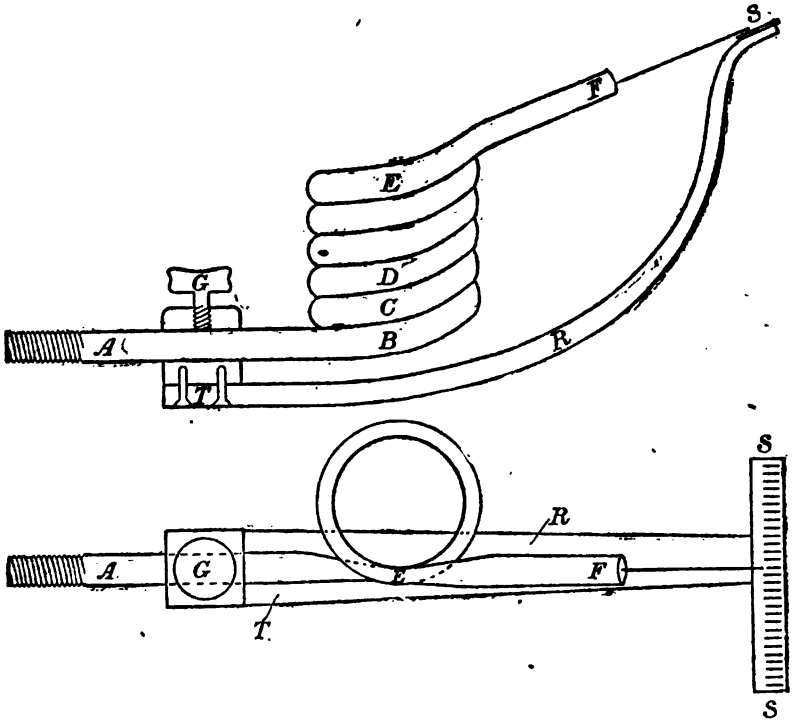
No. 1.	No. 4.	P_1.*	P_4.
Cm.	*Cm.*	*Atm.*	*Atm.*
— ·40	12·40	0	0
8·38	16·45	244	252
18·23	20·85	517	525
28·43	25·40	801	807
38·36	29·80	1077	1081
50·04	34·91	1401	1399
59·93	39·41	1675	1678
63·75	41·25	1781	1791
55·03	37·33	1540	1549
42.89	32·06	1202	1221
31·90	27·19	897	919
20·09	21·86	569	588
9·02	16·78	262	272
— ·55	12·30	— 4	6

TABLE 8.—*Calibrations of Tait gauges Nos. 1 and 4.*

Small Bourdon.	No. 1.	No. 4.	Factor No. 1.	Factor No. 4.
Atm.	*Cm.*	*Cm.*		
0	— ·56	12·36	3·57	1·60
100	2·90	13·93	3·73	1·66
200	6·59	15·56	3·58	1·61
300	10·35	17·26	3·51	1·57
300	10·34	17·26		
200	6·68	15·60	3·60	1·61
100	3·18	14·05		
0	— ·33	12·46		

Digitized by Google

20. *Tait gauge. Volume increase measured and computed.*—With the aid of the above results it will now be easy to compute the volume increase of the steel tube *qq*, Pl. I, 8, per atmosphere of internal pressure, and then compare the datum thus obtained with the result computed



FIGS. 2, 2*a*.—Direct reading helical Bourdon gauge.

by aid of Tait's formula.[1] From the dimensions a_0, a_1, L, ρ given in table 1, it follows that the increase of the external volume of the cylindrical steel tube is $47/10^6$ per unit of volume of *qq*, per centimeter of displacement of the thread in the capillary *ss*. This corresponds to a volume increase of

$$v/V = .00000080 \quad . \quad . \quad . \quad (1)$$

per unit of volume of the steel tube, per atmosphere.

Tait shows that in case of internal pressure the changes per unit of length tangentially to a cross section of radius r and longitudinally for any part of the tube, are respectively

$$\frac{\rho}{r} = \frac{\Pi a_0^2}{a_1^2 - a_0^2}\left(\frac{1}{3k} + \frac{a_1^2}{r^2}\frac{1}{2n}\right) \text{ and } \frac{d\xi}{dx} = -\frac{\Pi a_0^2}{a_1^2 - a_0^2}\frac{1}{3k}$$

[1] Tait: Challenger Reports, Vol. 2, 1882, Appendix A, p. 26.

Digitized by Google

Hence the increase, $\frac{v'}{V}$, per unit of volume of the external surface of the tube is

$$\frac{v'}{V} = 2\left(\frac{\rho}{r}\right)a^1 + \frac{d\xi}{dx} = \frac{\Pi a_0^2}{a_1^2 - a_0^2}\left(\frac{1}{k} + \frac{1}{n}\right) \quad . \quad . \quad . \quad . \quad (2)$$

Here ξ is the displacement of the point whose position is x centimeters from one end, and ρ the change of a point in a right section, originally distant r centimeters from the axis, Π the internal pressure in atmospheres, and k and n the compressibility and the rigidity respectively, of the steel employed. I take k and n from Everett's tables,[1] as follows:

$$k = 1.84 \times 10^{12} \qquad n = 8.2 \times 10^{11}$$

Inserting these quantities into the equation, there results

$$\frac{v'}{V} = .00000073 \quad . \quad . \quad . \quad . \quad (3)$$

It appears at once that this result is of the same order as (1). The difference is probably due to the constants k and n, which Prof. Everett doubtless found from a high-grade tool steel, whereas the above tubes, being made of low carbon steel, are nearer wrought iron in their properties. Beyond this the absolute gauge atmosphere is not vouched for; nor (being the mean value between 0 and 1000 atmospheres) are the coefficients at the end of table 1 quite free from thermal discrepancy.

When the observations are made for the purpose of measurement, there appears no doubt that equation (2) may actually be utilized to obtain serviceable values of $(1/k+1/n)$. For instance, a_0 may be obtained accurately by filling in vacuo with mercury and weighing, and then from the known specific gravity of the steel tube and its weight when empty, a_1 may be computed. ρ is similarly capable of accurate measurement. Therefore by combining (1) and (2), $(1/k+1/n)$ is measurable with the same accuracy with which Π is known.

21. *Direct reading, Bourdon gauge.*—It is well to insert my endeavors to adapt the Bourdon gauge for high pressures and direct reading. In order to achieve this result it is necessary to multiply the number of coils as well as to work with flat tubes. In Figs. 2 and 2*a*, the latter being the plan, the former the elevation, I have drawn a form of apparatus, with which I obtained some results. It consists essentially of a helix, *A B C D E F*, the spires of which do not touch each other. The end is provided with a needle *F S*, moving over a millimeter scale *S S*, supported by an arm *T R S*. This gauge is screwed directly into the barrel. Being entirely of iron and metal it is very firm. The spires are hammered flat by heating them to redness, the tube being

[1] Everett: Units and Physical Constants. London, Macmillan, 1879, p. 53.

Digitized by Google

originally 1^{cm} in external diameter and 5^{cm} in bore. After winding hot, the internal diameter of the helix was found to be somewhat larger than 4^{cm}. There were five spires in all, and the upper one $E\,F$, with its needle, extended about a decimeter beyond the helix.

The following little table gives the results of a comparison with the Bourdon gauge:

TABLE 9.—*Comparison of Bourdon gauge and the spiral gauge.*

Bourdon.	Spiral.	Bourdon.	Spiral.
Atm.	*Cm.*	*Atm.*	*Cm.*
0	0·00	600	1·28
100	·17	700	1·55
200	·35	800	1·87
300	·54	900	2·30
400	·76	1000	Explodes.
500	1·00	0	1·16

Constructing these results graphically in Fig. 3, it will be seen that between 0 and 300 atmospheres, the permanent set is not appreciable.

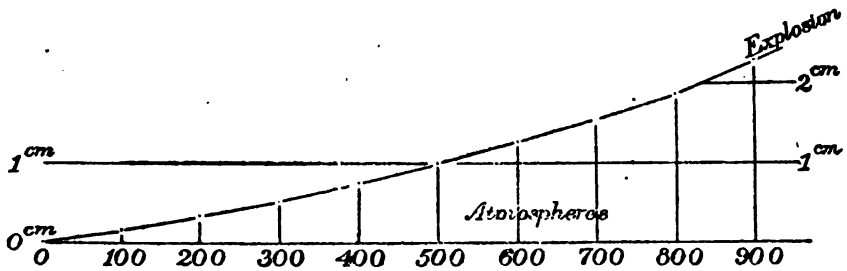


FIG. 3.—Chart showing the action of the helical Bourdon gauge.

When pressure was taken off, the fiducial zero reappeared. Above 300 atmospheres, however, permanent set becomes very marked. The helix was ruptured at 1,000 atmospheres, and the new zero after explosion indicates the large amount of permanent set during the course of the measurement. Connecting the final zero with the point for 900 atmospheres, a line is obtained nearly parallel to the line between 0 and 300 atmospheres. The mean motion of the index was therefore $\cdot0017^{cm}$ per atmosphere. Since high pressure measurement was only contemplated, the gauge would have been serviceable except for the occurrence of permanent set. The chief cause of this insuperable difficulty is the fact that to flatten the gauge it must be heated to redness. By so doing the drawn hardness and resilience is destroyed, and the soft metal of the gauge then becomes useless for measurement. Owing to the rupture of the tube I did not experiment further, since the coiling and flattening is a tedious operation. Clearly the gauge might be used without flattening by suitably attaching a minor index. But this complicates the apparatus.

22. *Concluding remarks.*—I will conclude this description by a few

Digitized by Google

general remarks on the apparatus used. It is clear that instead of a single barrel, two barrels, the axis of one of which is the prolongation of the other, suggest themselves. The barrels would be used alternately, one being filled while the other is emptied. Again, instead of having the screw enter the barrel, good results must also be obtainable by forcing a cylindrical shaft into the barrel; for the device shown at the end of the barrel *C C*, Pl. I, proves that the gasket of marine glue is quite as serviceable for cylindrical shafts as for screws. In case of a cylinder, however, the strain encountered in forcing in the shaft would be brought to bear on the bed plate, i. e., outside of the barrel. Specially strong devices would therefore have to be resorted to in bolting down the barrel, etc. These would make the apparatus, supposing the horizontal form retained, much more cumbersome. Indeed I conceived it to be an advantage of Andrews's screw, inasmuch as the chief stresses exist within the compass of the barrel. The necessary provision against twisting is much more easily applied. Finally I may state that it was my original object to obviate stuffing boxes altogether, by using a tinned screw *S T*. The maximum of pressure thus obtainable far exceeds the limits of the above screw-compressor with stuffing boxes. The tinned screw would have this disadvantage: it would have to be freshly coated whenever it became necessary to refill the barrel with oil, thus occasioning some loss of time. It is a device however, to be kept in mind, since it obviates the necessity of troublesome metallic gaskets, like those used in Mousson's well-known steel nut, for instance.

23. Cæteris paribus, the labor necessary in producing the above pressures decreases nearly as the fourth power of the diameter of the screw; for friction and leverage both increase as the radius, and the resisting pressure as the square of the radius. Similar advantage is gained by increasing the number of threads to the inch. Hence, by supposing the initial pressures to be produced by a thick screw (diameter 1 inch, say) at one end of the barrel, and the final pressures (above 2,000 atmospheres, when the inclosed liquids have become much more incompressible) produced by a thinner screw (diameter half an inch, say) at the other end of the barrel, the practical efficiency of the screw compressor would be increased. In such a case the piezometer tube must be vertical. (§ 12.) However, in limiting my present work to 2,000 atmospheres, I have by no means exhausted the power of the above machine. My purpose in doing so was to avoid straining the gauges. I add, in concluding, that among the facilities of the above screw compressor is the almost micrometric accuracy with which pressure can be raised to and maintained at a given value for any reasonable length of time.

24. The facility with which the Tait gauge may be replaced by Amagat's manometer, the absolute calibration of the Tait gauge, its availability for the measurement of pressures indefinitely high, and allied subjects will be considered in chapter III.

Digitized by Google

CHAPTER II.

THE ISOMETRICS OF LIQUIDS.

25. Utilizing the advantages of the screw compressor described in the foregoing chapter, I made the following investigation on the isometrics of liquid matter: The nature of the problem is clearly defined by the results of an earlier paper,[1] where it appears, conformably with the inferences of Dupré, Levy, Ramsay and Young, and Fitzgerald, that liquid isometrics are lines of small curvature.[2] It is thus the purpose of the present work to investigate the amount of deviation from a straight line as accurately as possible.

The word "isometric" is used by J. Willard Gibbs[3] in his researches on graphic methods in the thermodynamics of fluids. It has the advantage of priority if not of expressiveness, and I do not feel the need of withdrawing "isometric" for "isochore," as do Ramsay and Young.[4]

APPARATUS.

26. *Constant volume tube.*—The criterion for constant volume is to be given by a reliable electric contact. The liquid whose isometrics are to be determined is inclosed in a tube of constant volume, of the form

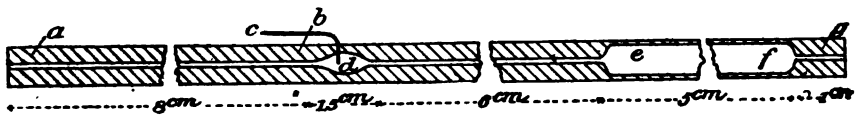


FIG. 4.—Constant volume tube; longitudinal section.

shown in Figs. 4 and 5. This tube consists of three parts, a reservoir *ef* and two capillary stems *ed* and *da* separated by an enlarged portion *d*. A platinum wire *c*, passing through the walls of the tube, enters the cavity *d*, for the purpose of securing electric contact, as shown in Fig. 5. The dimensions of the tube are given in Fig. 4, and the choice made is such as to admit of its easy introduction into the steel piezometer tube *uu*, chap. I, Pl. I, Fig. 6.

Fig. 5 (diagram) shows the tube ready for use. The end of the tube *g* is sealed, holding the platinum wire *mm*, which passes quite through the reservoir *ef* into the capillary stem. The substance having been

[1] Bull. U. S. Geol. Survey, No. 92, 1892, chap. I, p. 54.
[2] Am. Jour., 3d ser., vol. 39, 1890, pp. 497 et seq.
[3] Gibbs: Trans. Connecticut Acad., vol. II (2), p. 311, 1873; cf. ibid., p. 382.
[4] Ramsay and Young: Phil. Mag. (5), vol. 23, p. 435, 1887.

Digitized by Google

introduced into *ef*, completely fills this space and about one-half of the adjoining stem. The remainder of the tube is filled with mercury *kk*, care being taken to guard against inclusions of air.

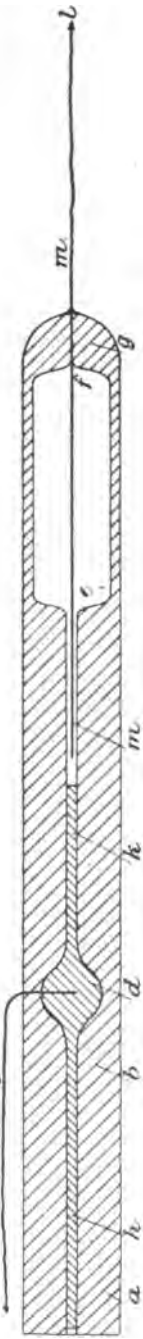


FIG. 5.—Constant volume tube; diagram.

The tube thus adjusted is inserted into the piezometer, and the terminal *c* put in metallic connection with the walls of the steel tube, near *V*, Pl. I. The terminal *ml* is insulated by a glass tube,[1] and after passing through the piezometer into the barrel, is there put in metallic connection with one of the vertical screws *M*. It will be remembered the barrel and piezometer are not in electric contact. A serviceable way of connecting the terminal with the barrel is shown in Fig. 6, where *BB* is part of the wall of the barrel. *S* is a perforated screw, slotted on its upper face, so that it can be inserted or removed easily. The end of the terminal *lo* is passed through the hole in *S*, and then coiled helically, as shown in the figure. The tinned screw *M* is now inserted so as to bind the helix between its lower face and *S*. This insures electric contact. A similar device is utilized at *V*, Pl. I, Fig. 6, and the glass tube is thus held in horizontal position within the steel piezometer tube, by aid of its two tense terminals.

Before introducing the constant volume tube, both piezometer and barrel must be quite filled with oil, and the screws *M* and *V*, Pl. I, are to be so fastened that air may be as far as possible excluded.

27. *Manipulation.*—Supposing the constant volume tube in place, surrounded with oil, the screw *SS* (Pl. I) is forced in. The pressure thus brought to bear uniformly on all parts of the tube, moves the thread of mercury inward by an amount corresponding to the compression of *ef*. Eventually, therefore, the meniscus near *k* and the sharp end of the platinum terminal near *m* come into electric contact. Now, as barrel and piezometer are in a simple circuit, including a suitable galvanoscope and a battery, a deflection in the galvanoscope occurs at the moment of contact.[2] This method of registration is very sharp and thoroughly reliable. Pressure is applied by means of a screw, and can be diminished or intensified with great nicety. Hence the position of the meniscus *k* can be controlled with almost micrometric precision, even when the pressures are as high as 2,000 atmospheres.

[1] Rubber and other similar insulations are fused or dissolved at high pressure, and are therefore unsuitable.

[2] Devices of this kind have been much used by Weinhold, Crafts, Mendenhall, and others.

Digitized by Google

When the machine is in satisfactory adjustment contact can be made and broken at *km* without apparent variation of pressure, the difference being in fractions of an atmosphere. The delicacy, however, depends on the relative caliber of capillary tube and reservoir tube.

To avoid breakage of the thread *k* on being forced through *m*, the free end must be made as fine as practicable (·01^{cm} in diameter, say). Hence it is advisable to weld a fine wire to the relatively thick terminal *m* (diameter 0·5^{cm}).

28. In passing from one constant temperature to another, care must be taken to avoid the mercury thread from being forced either out of the tube or into the reservoir. This may be done by keeping the meniscus *k* always very nearly in contact with *m*. Hence, when a vapor bath is attached and the burner started, pressure is increased in such a way as to keep the contact just made. On the other hand, when temperature decreases, pressure is relieved in such a way as just to keep the contact broken.

29. When the series of isometrics are to be mapped out, the volume of liquid between the meniscus *k* and the sharp end of *m* is suitably changed. This volume may be conceived as either positive or negative. In the latter case the wire *m* penetrates the thread *k*. The advantage of such an arrangement is shown below.

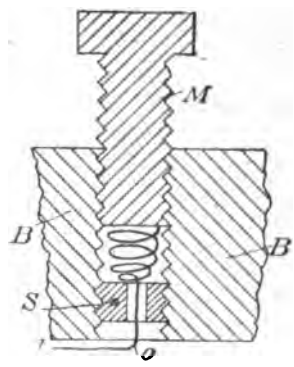


FIG. 6.—Method of fastening the terminals.

30. *Method of filling.*—When the substance to be compressed (*ef*, Fig. 5) is liquid at ordinary temperatures, like ether or water, the tube may easily be filled without an air pump, by making use of filamentary glass tubes with enlarged funnel-shaped heads. The filamentary end is introduced at *a* and pushed down to the bottom *g*, supposing the tube *ag* to be vertical and *a* uppermost. The liquid is allowed to run throughthe funnel, the top of which is kept filled until the reservoir *ef* and adjoining capillaries *eda* are quite filled. The operation is not stopped however until three or four times as much liquid has run through *ef* as is necessary to fill it.

The tube is now tipped nearly horizontal and mercury passed into the bulb *d* by aid of similar funnel capillaries. The thread is then pushed forward from *d* into *de* by aid of an empty glass filament, by successively draining off small parts of the liquid in *de*, until the meniscus *k* has the desired proximity to *m*.

31. The greatest care must be taken to have all parts of the tube perfectly clean, to use pure, fresh mercury, and *to avoid rubber connections or other material impregnated with sulphur.* I find it desirable to draw off the mercury in *abd* by aid of a fine tube and a jet suction pump, and thus to thoroughly dry out this part of the stem. Fresh mercury

Digitized by Google

is then poured in through the glass filament until the tube is again full.

When the mercury appears dead or fails to move as an unbroken column the tube is worthless. The cause of this by no means infrequent annoyance is usually found in the presence of sulphurous dirt in the tubes or of sulphide in the sample liquid. It is advisable therefore to use fresh tubes only.

32. When the substance is solid like thymol or diphenylamine, it must be introduced by aid of an air pump. For this purpose a wide glass tube about 20^{cm} long is fused to the end *a*, Fig. 5. Into this the solid substance is put, after which the open end of the wide tube is drawn out to a filament and connected with the air-pump. After the exhaustion of the system the solid is fused with a burner and allowed to run down into *ef*. The operation must be repeated many times and use made of vacuum ebullition to expel the last traces of air. The thread of mercury is introduced in the way already stated (§ 30), except in so far as it is essential to keep the tube in a warm bath to prevent solidification. When in adjustment it is inserted into a hot piezometer tube. These operations call for much skill on the part of the operator. If solidification occurs the mercury thread is drawn down into the bulb in consequence of the large volume contraction, and the charge is therefore lost.

33. *Vapor baths.*—In order that the isometrics may be sharply traced, temperature must be regulated to a nicety. This is not easy, seeing that the metallic piezometer tube is a good conductor. Hence the forms of vapor baths used in my earlier similar works[1] are not applicable here. It is essential that vapor be directly in contact with the surface of the piezometer tube and that the reservoir of the constant volume tube be at a distance of 3 or more centimeters from the end walls of the bath.

Substances useful for vapor baths are methyl alcohol, 60°; water, 100°; amyl alcohol, 130°; turpentine, 160°; naphthalene, 215°; benzoic acid, 250°; diphenylamine, 310°; phenanthren, 350°, and others These form a convenient series. They admit of being boiled in a brazed copper vessel and decompose very slowly. The fiducial or initial temperature is obtained by allowing a current of water from the hydrant to circulate around the piezometer tube.

At temperatures above 200°, the form *ffff* shown in Pl. I, 6, is serviceable. The tubulures *hh* through which the piezometer passes may be closed with perforated cork stoppers.[2] At higher temperatures *hh* are screw stuffing boxes, securing asbestos jackets. The vapors issuing from *yy*, the ebullition liquid (usually solid at ordinary temperature), are condensed in a lateral tube (not shown) and run back into the drum *ffff*. The thermocouple is inserted through *g*.

[1] Bull. U. S. Geol. Surv. No. 92, p. 22; Am. Journal Sci. (3), vol. 39, p. 482, 1890.

[2] Rubber stoppers melt and are otherwise very objectionable above 200°.

Digitized by Google

34. At temperature below 200°, this form of vapor bath is not convenient, since the substance *yy* is usually liquid and too easily spilt. Moreover the degree of constant temperature obtainable in the drum *ffff* is probably insufficient. I therefore employed the circulating system shown in Fig. 7. Vapor is introduced into the drum *fff* from the boiler *A* and the influx pipe *B*. It is condensed in the tube *C C* carrying the cold water jacket *D D*. The condensed liquid falls into the funnel *E*, which is cylindrical and thus subserves the purpose of a water gauge. The piezometer tube is shown at *U u u U* with the constant volume tube *adeg* in place. *G* and *G* are cold-water jackets surrounding *UU* to prevent the spread of high temperatures along the tube. A

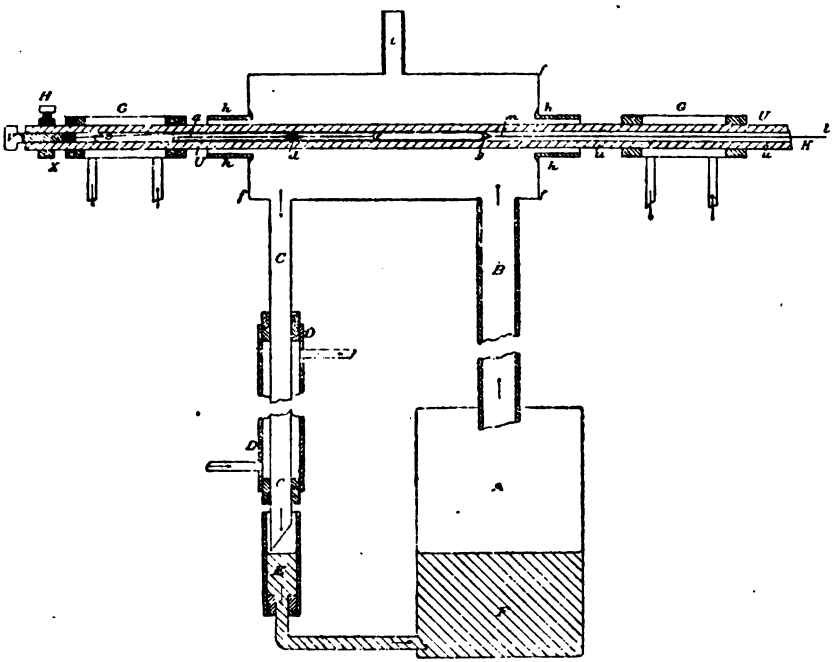


FIG. 7.—Vapor bath and piezometer tube; longitudinal section.

ingle current of water (issuing from the gauge jacket, Pl. I, 8, above) asses through *G*, *D*, and *G*. This current is shunted, so that *G D G* an be cut out at pleasure and the vapor bath removed or replaced by circulating water bath. It is to be noted that the parts of the vapor ath are rigidly connected, so that it can be rapidly withdrawn as a hole. *H* is a suitable electric clamp, corresponding to the other termial *K*. All parts of the vapor bath are heavily jacketed with asbestos. It is necessary that the vapor baths slide off and on easily. Any olent jarring of the piezometer tube will break the thread in the glass be within.

35. *Method of cooling piezometer.*—To cool the tube *UU* after the vapor th has been removed, it is convenient to oil the piezometer with vase-

Digitized by Google

line. The jacket G may then be slid to and fro very rapidly at first, care being taken to relieve the pressure in proportion as the tube cools.

36. *Method of temperature measurement.*—For the measurement of temperature I used a platinum platinum-iridium thermocouple, the electromotive force of which was expressed in terms of the torsion of the platinum fiber which suspended the given astatic system. The torsion galvanometer serviceable for thermo-electric work I have already described elsewhere.[1] To calibrate this apparatus the boiling points of water and of mercury were first used. Finally I made elaborate comparisons with the reentrant glass air thermometer. §§ 48–50.

37. *Method of pressure measurement.*—Pressure was measured in terms of the expansion of a given cold-drawn steel tube, as detailed in chapter I.

It is needless to say that the factor of the gauge was frequently checked during the course of the work. A small sensitive 300-atmosphere Bourdon gauge with a tinned screw connection is very convenient for this purpose. About twenty or thirty minutes were allowed to secure isothermal conditions both for the gauge and the piezometer tube. Leaks of the apparatus must be so far as possible avoided, inasmuch as continued pumping changes the thermal state of the liquids operated on and is therefore a fertile source of error.

PRELIMINARY RESULTS.

37. *Data for ether.*—The data of Tables 10 and 11 were obtained in the earlier experiments. Although neither the gauge nor the thermocouple was remarkably sensitive, these results bear directly on the matter below and must therefore be inserted. P and θ are corresponding values of pressure and temperature, such that the volume of ether remains constant. Two or three observations were made for each datum, allowing five minutes' time per observation. This is essential where isothermal conditions are to be guaranteed. So far as these observations go, the corrections for volume changes of glass are negligible. During the first five series, extending over an interval between March 14 and 19 the constancy of the fiducial pressure (at about 10°) is to be noted. In the remaining series it was not always possible to regain the fiducial pressure, owing to accidents.

TABLE 10.—*Isometrics of ether. Preliminary results.*

P.	θ.	P.	θ.
Atm.	°*C.*	*Atm.*	°*C.*
293	11·6	887	66
305	11·6	1237	100
888	66	1242	100
888	66	1247	100
1227	100	284	11·0
1231	100	288	11·2
300	11·6		
301	11·6	287	10·0
885	66	287	10·0

[1] Barus: Phil. Mag. (5), vol. 29, p. 146, 1890.

Digitized by Google

TABLE 10.—*Isometrics of ether. Preliminary results*—Continued.

P.	θ.	*P.*	θ.
Atm.	°*C.*	*Atm.*	°*C.*
276	9·4	101	9·8
289	9·9	647	66
		645	67
277	9·8	972	103
1502	127	966	103
1510	128	1080	119
1482	128	1063	121
1480	128	51	10·0
279	9·7	1443	155
		1436	158
278	10·8	91	10·9
875	64		
868	66	80	10·3
874	65	608	66
286	9·7	611	66
		613	66
14	9·8	614	66
545	67	614	65
545	67	925	99
859	102	924	101
857	102	921	101
		920	101
65	10·6	919	100
595	64	84	10·3
602	64	1112	119
597	63	1112	120
		1380	153
71	10·8	1421	156
912	101	1451	161
914	100	1446	162
76	10·8		
		94	11·2
156	10·8	627	66·5
1087	114	630	66·4
1094	115	926	98·8
		924	98·5

TABLE 11.—*Digest of these data.*

Δ*p*	θ	Δθ		Δ*p*	θ	Δθ	
0	11·5	0		0	9·9	0	
589	66	55		570	66	56	
937	100	89		893	103	90	(3)
				996	120	110	
0	9·8	0	(1)	1369	156	146	
1216	127	117					
				0	10·3	0	
0	10·2	0		530	66	56	
590	65	56		840	100	90	
				1030	120	110	
0	9·8	0		1342	158	148	(4)
531	67	56					
844	102	90		0	11·2	0	
				534	66	55	
0	10·7	0		831	99	89	
530	64	55	(2)				
840	100	89					
0	10·8	0					
934	114	103					

38. *Discussion.*—In the digest, Table 11, the coordinates have been shifted, so that the fiducial pressure and temperature are now zero. The graphic representation, Fig. 8, shows a distribution of points lying very closely along straight lines. So far as these data go, therefore, the linear character of the isometrics is maintained. The rates per atmosphere are respectively ·095°, ·107°, ·106°, ·107°.

Digitized by Google

DEFINITE RESULTS.

39. ***Apparatus improved.***—With the above data in hand I endeavored to carry the discrimination one step further by increasing the sensitiveness of both the pressure gauge and the thermocouple.

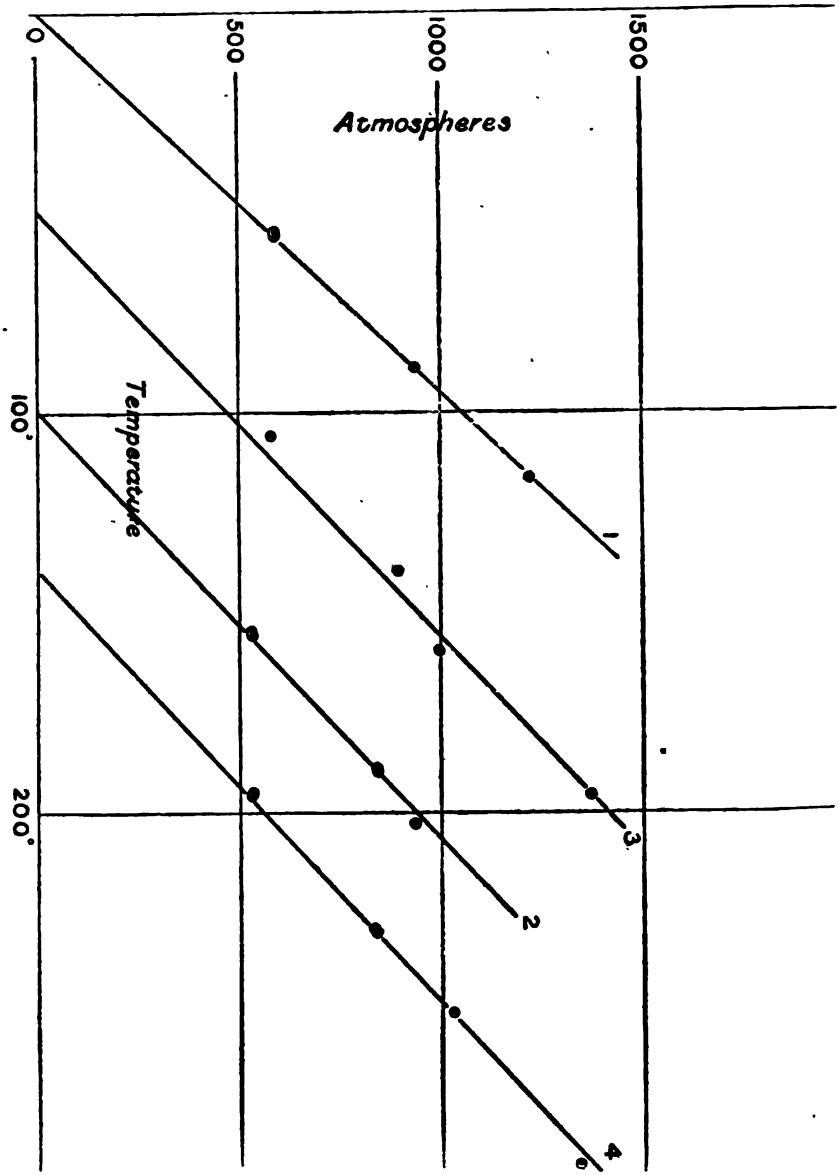


FIG. 8.—Isometrics of ether; preliminary results.

Using the same steel tube for the registration of pressures by Hooke's law, as before, the gauge was made much more delicate by decreasing the caliber of the capillary measuring tube (*ss*, Pl. I, 6), and by

Digitized by Google

making use of a more close-fitting glass jacket *tt* than before. The results have already been shown (§§ 15 to 19). Apart from errors due to viscosity and thermal effects, the gauge was sufficiently sensitive to register fractions of an atmosphere at 2,000 atmospheres.

Particular care was taken to redetermine the initial pressure corresponding to the initial or fiducial temperature (about 15°), before and after each high-temperature observation. This is a certain check on the validity of the results obtained.

Again the temperature measurement was made more delicate by inserting a finer platinum fiber in the torsion galvanometer. Statistics will be given below.

At least ten minutes were allowed for each datum of pressure and temperature given. In proportion as the second of any two measurements made at a given temperature coincides with the first, the inference is warranted that the thermal effects of compression are fully dissipated. The observation at any temperature therefore lasted twenty or thirty minutes.

40. *Notation.*—The notation is as follows:

N'_θ, deflection in degrees of arc observed at the torsion galvanometer;

t, temperature of the cold junction of thermocouple;

n_θ, correction by which N'_θ is reduced to N_θ, the deflection which would be observed at the torsion galvanometer if $t = 20°$;

θ, temperature of the vapor bath surrounding the piezometer tube. θ is computed from N_θ. θ is therefore the temperature of the reservoir of the constant volume tube.

N_p, reading in centimeters observed at the capillary tube of the pressure gauge.

p, pressure corresponding to N_p in atmospheres. Hence p is the pressure bearing on the substance in the constant volume tube;

Δp, $\Delta\theta$, pressure and temperature obtained by shifting the coordinates, so that the initial pressure and temperature may be zero.

41. *Data for ether.*—Table 12 contains fifteen series of observations made with ether. Series in which the constant volume tube and contents were changed are separated by heavy lines. It is necessary to consider these data somewhat in detail. Each series contains at least one observation at the boiling point of water. Since the barometer was also noted, the data for the final reduction of the values θ are at hand—cf. §§ 48 et seq.

The first eight series need but little comment. In the first the gauge reading for $p = 0$ was -1.00^{cm}; in the second, third, fourth, fifth it was -2.00^{cm}; in the sixth, -3.50^{cm}; in the eighth, 1.70^{cm}. Inasmuch as the relation between p and v is nearly linear, the gauge reading for $p = 0$ is of secondary importance. Owing to accidents the fiducial reading was lost at the end of the sixth and eighth series.

42. Comparing the first eight series with the remaining seven, it is seen that the fiducial pressure is very much more constant in the

Digitized by Google

former than in the latter; for the reading at the initial temperature in the one case does not vary more than 5 or 10 atmospheres; whereas in the other the variation is as large as 100 atmospheres. The cause of this discrepancy is a strain permanently imparted to the gauge at the end of the eighth series, where it was necessary to work the machine with great violence and much above the pressure given, to counteract an accidental leak. Hence in constructing Δp for these series (9 to 15) I deduct the fiducial pressure *preceding* and *following* any pair of high temperature data from the first and last of these data respectively. In this way the viscous error of the gauge is eliminated. Of the two values of Δp thus obtained at each temperature, the latter is the more nearly correct, since it has been coordinated with the fiducial pressure immediately following it. As the work proceeds, that is, in the thirteenth, fourteenth, and fifteenth series, the fiducial pressure is again more nearly constant, showing a gradual increase of the viscosity of the gauge.

43. In the ninth and tenth series, $p = 0$ is at $-.70^{m}$; in the eleventh, at $-.30^{m}$; in the thirteenth, fourteenth, and fifteenth, at $.50^{m}$. The last three series (13–15) were obtained with the same tube, and the work, done continuously, was throughout very satisfactory. Moreover the change of fiducial pressure still marked in series thirteen becomes of less prominence in the last two series. These therefore were selected for the digest below.

44. *Method of purifying.*—The ether employed was thoroughly dried with sodium, and then distilled in a small flask at a temperature only slightly above the boiling point. All parts of the condenser tube and flask were fused together, and rubber connections were scrupulously avoided. The distillation was frequently repeated, and the ether then at once used for filling the constant volume tube. I can not guarantee, however, that the ether after being introduced in the tube was quite free from water; for during the necessary manipulations some absorption of water out of the air was unavoidable.

45. *Observations for ether.*—The data for ether are as follows:

TABLE 12.—*Isometrics of ether. Observations.*

N'_{θ}.	t.	n_{θ}.	N_p.	θ.	p.	N_{θ}.	Δp.	$\Delta\theta$.
°	°C.	*Cm.*	*Cm.*	°C.	*Atm.*	°C.	*Atm.*	
I.			— ·54	15·1	40		0	·0
4·115	22·2	·192	+16·67	67·5	512	4·307	474	52·2
4·132	22·3	·200	+16·86	67·6	517	4·332	479	52·3
			— ·70	15·5	36		0	·0
7·191	22·3	·200	+27·20	99·5	800	7·391	762	84·0
7·209	22·3	·200	+27·29	99·6	803	7·409	765	84·1
			— ·50	15·5	41		0	·0
II.			— ·23	15·4	48		0	·0
13·115	23·1	·270	+45·89	157·9	1,312	13·385	1,272	142·4
13·176	23·7	·321	+46·12	158·8	1,318	13·497	1,278	143·3
			— ·10	15·5	52		0	·0
6·946	24·8	·418	+28·01	99·2	822	7·364	778	83·9
6·890	25·0	·428	+28·00	98·8	822	7·328	778	83·5
3·849	25·0	·438	+17·59	67·2	537	4·287	493	51·9
3·849	25·0	·438	+17·61	67·3	537	4·287	493	52·0
			— ·69	15·0	36		0	·0

Digitized by Google

TABLE 12.—*Isometrics of ether. Observations*—Continued.

N'_θ.	t.	n_θ.	N_θ.	θ.	N_p.	p.	$\Delta\theta$.	Δp.
III.				15·9	1.55	44	·0	0
7·132	22·9	+·254	7·386	99·5	28·95	793	83·6	755
7·100	23·0	·262	7·362	99·0	29·03	795	83·1	757
				15·9	1·20	33	·0	0
IV.				16·2	1·18	32	·0	0
15·337	23·8	·333	15·670	178·7	53·56	1,467	162·5	1,439
15·390	23·8	·333	15·723	179·2	53·65	1,470	163·0	1,442
				16·2	·80	25	·0	0
V.				15·9	— ·40	44	·0	0
16·403	20·8	·068	16·471	185·7	53·51	1,521	169·8	1,472
16·465	20·9	·076	16·541	186·4	53·38	1,517	170·5	1,468
16·536	21·1	·095	16·631	187·3	53·06	1,509	171·4	1,460
				15·8	— ·04	54	·0	0
7·297	21·3	·112	7·409	99·8	27·97	821	83·9	767
7·282	21·3	·112	7·394	99·5	27·97	821	83·6	768
				15·9	— ·08	53	.0	0
VI.				16·0	·00	96	·0	0
7·294	20·7	·059	7·353	98·2	28·59	879	82·2	783
7·294	20·7	·059	7·353	98·2	28·62	880	82·2	784
VII.				16·0	— 1·20	63	·0	0
7·083	22·5	·218	7·301	97·7	26·88	832	81·6	767
7·068	22·6	·226	7·294	97·5	27·01	835	81.4	770
4·165	22·6	·226	4·291	67·1	16·81	556	51·0	491
4·074	22·6	·226	4·300	67·4	16·87	558	51·3	493
				16·2	— ·97	69	·0	0
VIII.				16·4	+ ·98	73	·0	0
7·144	22·2	·192	7·336	98·1	29·51	854	81·7	781
7·118	22·4	·209	7·327	98·0	29·55	856	81·6	783
20·450	22·8	·243	20·293	219·5	65·31	1,836	203·01	1,763
20·044	22·9	·251	20·295	219·6	65·20	1,833	203·2	1,760
IX.				16·5	+ 4·94	154	·0	0
3·893	23·9	·342	4·235	66·9	23·51	663	50·3	509
3·926	23·9	·342	4·268	67·0	23·73	669	50·4	515
6·890	24·2	·367	7·257	97·4	34·91	976	80·8	822
6·911	24·3	·375	7·286	97·5	35·01	978	80·9	824
				16·7	+ 6·38	1194	·0	

N'_θ.	t.	n_θ.	N_θ.	θ.	N_p.	$\Delta\theta$.	p.	Δp.
X.				16·6	1·18	0	32	0
7·303	21·0	·087	7·390	99·5	28·33	83·0	776	740
7·309	21·2	·104	7·413	99·8	28·41	83·3	778	742
				16·5	1·48	0	40	0
XI.				16·6	1·60	0	44	0
4·206	22·0	·175	4·381	68·0	18·91	51·4	518	465
4·177	22·2	·192	4·369	68·0	18·96	51·4	520	467
7·191	22·2	·192	7·383	99·2	29·14	82·6	798	745
7·180	22·2	·192	7·372	99·0	29·20	82·4	800	747
				16·6	2·28	0	62	0
XII.				16·6	2·82	0	77	0
4·133	22·4	·209	4·342	67·9	20·10	51·3	551	463
4·136	22·5	·219	4·355	68·0	20·15	51·4	552	464
7·071	22·7	·224	7·295	98·5	30·19	81·9	827	739
7·080	22·8	·243	7·323	98·8	30·34	82·2	831	743
				16·6	3·58	0	98	0
12·961	23·1	·270	13·231	156·3	50·61	139·7	1387	1289
13·077	23·2	·279	13·356	157·6	50·64	140·9	1388	1208
				16·7	6·59	0	180	0
15·722	23·3	·287	16·009	182·0	56·74	165·3	1555	1370
15·725	23·4	·296	16·021	182·0	56·71	165·3	1554	1369
				16·7	6·87	0	189	0
XIII.				17·6	1·61	0	44	0
4·033	23·2	·279	4·312	67·5	17·86	49·9	489	439
4·033	23·3	·287	4·320	67·6	17·88	50·0	490	440
6·896	23·5	·306	7·202	97·5	27·59	79·8	756	706
6·896	23·6	·313	7·209	97·5	27·61	79·8	757	707
				17·7	2·05	0	56	0
12·834	24·2	·367	13·201	156·2	45·52	138·5	1247	1191
12·822	24·2	·367	13·189	156·0	45·52	138·2	1247	1171
				17·8	2·78	0	76	0
19·540	24·8	·418	19·958	216·5	62·60	198·7	1715	1639
19·540	24·9	·426	19·966	216·6	62·59	198·7	1715	1611
				17·9	3·81	0	104	0

Digitized by Google

TABLE 12.—*Isometrics of ether. Observations*—Continued.

N'_θ.	t.	n_θ.	N_θ.	θ.	N_p.	p.	$\Delta\theta$.	Δp.
XIV.				17·8	3·80	104	0	0
7·147	21·2	·104	7·251	98·2	29·79	816	80·4	712
7·132	21·3	·112	7·244	98·0	29·80	819	80·0	701
				18·0	4·29	118	0	0
20·080	21·7	·146	20·226	218·8	64·30	1761	200·8	1643
20·071	21·8	·155	20·226	218·8	64·30	1761	200·7	1619
				18·1	5·19	142	0	0
4·144	22·2	·192	4·336	67·8	21·14	579	49·7	437
4·147	22·3	·200	4·347	68·0	21·14	579	49·9	437
				(18 1)	(5·20)	(142)	0	0
13·177	22·3	·200	13·377	157·8	49·04	1344	139·7	1202
13·194	22·3	·200	13·394	157·9	49·06	1344	140·0	1196
				17·9	5·39	148	0	0
XV.				17·4	4·18	114	0	0
20·371	20·0	0	20·371	220·2	64·17	1758	202·8	1644
20·353	20·0	0	20·353	220·0	64·16	1758	202·6	1642
				17·4	4·23	116	0	0
7·312	20·8	·068	7·380	99·1	30·83	845	81·7	729
7·265	20·8	·068	7·333	98·8	30·84	845	81·4	723
				17·4	4·45	122	0	0
4·397	21·0	·087	4·484	69·1	21·37	586	51·7	464
4·415	21·0	·087	4·502	69·4	21·35	585	52·0	464
				17·4	4·43	121	0	0
13·306	21·2	·104	13·410	158·0	48·93	1341	140·6	1220
13·330	21·3	·112	13·442	158·3	48·98	1342	140·9	1209
				17·4	4·86	133	0	0

46. *Observations for alcohol.*—Table 13 contains data for alcohol corresponding to those already given for ether. The two series, obtained with the same tube on successive days, are satisfactory throughout. The arrangement of data has been already explained.

The alcohol used was kindly furnished me by Dr. Stokes. I redistilled it over lime in small quantities immediately before filling the constant volume tube. Nevertheless some absorption of moisture from the air during the manipulations was not avoidable.

TABLE 13.—*Isometrics of alcohol. Observations.*

N'_θ.	t.	n_θ.	N_θ.	θ.	N_p.	p.	$\Delta\theta$.	Δp.
				17·2	4·92	135	0	0
4·485	20·3	·025	4·510	69·5	25·46	697	52·3	562
4·491	20·3	·025	4·516	69·7	25·46	697	52·5	556
				17·2	5·14	141	0	0
7·285	20·7	·059	7·344	98·9	37·67	1032	81·7	891
7·282	20·8	·068	7·350	99·0	37·68	1032	81·8	888
				17·2	5·27	144	0	0
13·427	21·0	·087	13·514	159·0	63·04	1727	141·8	1583
13·424	21·0	·087	13·511	159·0	63·04	1727	141·8	1575
				17·2	5·53	152	0	0
				17·0	4·92	135	0	0
7·377	19·9	—·008	7·370	99·2	37·72	1034	82·2	899
7·356	20·0	±·000	7·356	99·1	37·70	1033	82·3	893
				16·8	5·12	140	0	0
13·547	20·4	·034	13·581	159·7	63·20	1732	142·9	1592
13·541	20·5	·042	13·583	159·7	63·15	1730	142·8	1582
				16·9	5·39	148	0	0
				16·9	5·39	148	0	0
4·100	22·2	·192	4·292	67·4	25·14	689	50·5	541
4·090	22·2	·192	4·282	67·0	25·16	689	50·0	533
				17·0	5·69	156	0	0
7·106	22·4	·209	7·315	98·9	38·36	1051	81·9	895
7·077	22·4	·209	7·286	98·5	38·36	1051	81·5	884
				17·0	6·11	167	0	0

Digitized by Google

47. *Observations for thymol, para-toluidine, and diphenylamine.*—Tables 14, 15, 16 contain results for thymol, para-toluidine, and diphenylamine, arranged on the same plan as Tables 12 and 13. Thymol is particularly convenient since, after firing, it admits of undercooling much below its melting point. Observations can thus be made even at 17°. In case of the other two substances this is possible to a less extent, and it is necessary to insert the constant volume tube into a hot piezometer. A large bath of heated water must be at hand to prevent freezing during the manipulations. (§ 32.)

TABLE 14.—*Isometrics of thymol. Observations.*

N'_θ.	t.	n_θ.	N_θ.	θ.	N_p.	p.	$\Delta\theta$.	Δp.
4·227	20·7	·059	4·286	67·1	32·65	895	49·9	704
4·253	20·8	·068	4·321	67·5	32·69	896	50·3	705
7·259	20.8	·068	7·327	98·8	49·11	1346	81·6	1155
7·235	20·9	·076	7·311	98·6	49·16	1347	81·4	1156
4·282	21·0	·087	4·369	68·1	33·02	905	50·9	714
4·324	21·0	·087	4·411	68·5	33·07	906	51·3	715
				17·2	6·97	191	0	0
7·230	21·1	·095	7·325	98·9	49·62	1360	81·7	1169
7·221	21·2	·104	7·325	98·9	49·69	1361	81·7	1160
				17·2	7·35	201	0	0
9·652	21·7	·146	9·798	123·5	62·40	1709	106·3	1508
9·648	21·7	·146	9·792	123·4	62·35	1708	106·2	1495
				17·2	7·77	213	0	0
				17·0	7·78	213	0	05
4·306	20·5	·042	4·348	68·0	34.08	934	51·0	721
4·300	20·4	·034	4·334	67·8	34·11	935	50·9	729
				16·9	7·51	206	0	0
7·288	20·4	·034	7·322	98·9	50·07	1372	82·0	1166
7·315	20·4	·034	7·349	99·0	50·06	1372	82·2	1171
				16·8	7·34	201	0	0
9·875	20·4	·034	9·909	124·5	62·49	1713	107·7	1512
9·958	20·3	·025	9·983	125·3	62·58	1715	108·5	1506
				16·8	7·63	209	0	0

TABLE 15.—*Isometrics of para-toluidine. Observations.*

N'_θ.	t.	n_θ.	N_θ.	θ.	N_p.	p.	$\Delta\theta$.	Δp.
4·206	21·5	·131	4·337	67·8	15·34	420	0	0
4·182	21·6	·138	4·320	67·5	15·32	420	0	0
7·147	21·8	·155	7·302	98·5	31·84	872	31·0	452
7·132	21·8	·158	7·290	98·4	31·79	871	30·4	441
4·162	22·3	·200	4·362	68·0	15 69	430	0	0
4·153	22·3	·200	4·353	67·9	15·66	429	0	0
9·578	22·5	·218	9·796	123·5	45·20	1238	55·6	809
9·572	22·6	·226	9·798	123·5	45·24	1239	56·0	799
4·071	22·8	·245	4·316	67·5	16·06	440	0	0
4·100	22·8	·245	4·345	67·9	16·04	439	0	0
13·000	23·1	·270	13·270	156·7	57·51	1576	88·8	1137
13·006	23·2	·279	13·285	157·0	57·50	1575	89·1	1124
4·035	23·5	·306	4·341	67·9	16·45	451	0	0
4·027	23·6	·313	4·340	67·9	16·46	451	0	0

Digitized by Google

TABLE 16.—*Isometrics of diphenylamine. Observations.*

N'_θ.	t.	n_θ.	N_θ.	θ.	N_p.	p.	$\Delta\theta$.	Δp.
4·035	23·1	·270	4·305	67·5	18·01	493	0	0
4.027	23·1	·270	4·297	67·5	18·02	494	0	0
6·975	23·4	·298	7·273	98·2	36·26	993	30·7	499
6·969	23·4	·298	7·267	98·2	36·30	995	30·1	487
4·051	23·8	·330	4·381	68·1	18·53	508	0	0
4·059	23·8	·330	4·389	68·3	18·54	508	0	0
9·525	24·0	·350	9·875	124·1	51·95	1423	55·8	915
9·587	24·0	·350	9·937	124·9	52·29	1433	57·1	900
3·975	24·2	·367	4·342	67·8	19·46	533	0	0
3·981	24·2	·367	4.348	68·0	19·36	530	0	0

Another zero.

13·200	24·2	·367	13·567	159·6	65·15	1785	92·0	1346
13·171	24·3	·375	13·546	159·5	65·12	1784	91.9	1345
3·949	24·4	·384	4·333	67·6	16·02	439	0	0
3·955	34·4	·384	4·339	67·8	15·93	437	0	0
6·802	24·4	·384	7·186	97·3	33·49	918	29·5	481
6·834	24·4	·384	7·218	97·8	33·48	917	29·7	479
3·985	24·4	·384	4·369	68·1	15·98	438	0	0
4·012	24·4	·384	4·396	68·4	15·98	438	0	0
9·470	24·4	·384	9·854	124·0	49·34	1352	55·6	914
9·534	24·4	·384	9·918	124·8	49·39	1353	56·2	904
4·035	24·4	·384	4·419	68·5	16.39	449	0	0
4·021	24·3	·375	4·396	68·5	16.41	450	0	0

TEMPERATURES CORRECTED.

48. *Behavior of the torsion galvanometer.*—An inspection of the tables shows the temperatures to need correction, for the boiling points (water, for instance) are usually low. The cause of this discrepancy is to be sought in the temperature coefficient and perhaps also in the time coefficient of the magnets of the torsion galvanometer. This error is easily allowed for as follows: It is clear that the magnetic change which obtains affects all deflections (deflections for all temperatures) uniformly. Consequently if N'_θ be the twist corresponding to 100° on any day of observation, and if N_θ be the corresponding twist on the day of calibration, both observed at the same torsion galvanometer, then N_θ / N'_θ is the factor for the reduction of all temperature observations for the former day to the scale of the calibration day.

To test this inference I made two independent calibrations of the same couple about a month apart. The constants a and b given in Table 17, where $N_\theta = a\,(T-t) + b\,(T^2-t^2)$, show considerable variation during this interval.[1] Computing the twists N_θ and N'_θ for different temperatures T, when $t = 20°$, it is found that N_θ / N'_θ is constant within less than 3 per cent for the whole interval 50° to 400°. Clearly this is an error of observation, since the constants a and b never quite faithfully reproduce the calibration interval. Slight reciprocal changes of a and b, for instance, would wipe out the discrepancy $\Delta(N_\theta / N'_\theta)$, without appreciably slighting the observations.

[1] T, t are the temperatures at the junctions of the platinum platinum-iridium thermo-couple.

Digitized by Google

TABLE 17.—*Constants of the torsion galvanometer and couple. Comparisons of T, April 20 and May 27.*

April 20 $\begin{cases} a=.0844, \\ b=.0000717, \end{cases}$ May 27 $\begin{cases} a'=.0820. \\ b'=.0000694. \end{cases}$

[Computed from observations at 100° and 357°.]

T.	N_θ.	N'_θ.	N_θ/N'_θ.
°			
50	2·683	2·632	·9810
100	7·440	7·298	·9809
150	12·557	12·311	·9804
200	18·031	17·670	·9800
250	23·865	23·377	·9796
300	30·057	29·430	·9792
350	36·611	35·831	·9787
400	43·520	42·578	·9784

49. *Air thermometers comparison. Apparatus.*—There is a more serious question relative to the degree of truth of the interpolation equation $N_\theta = a\,(T-t)+b\,(T^2-t^2)$. This can only be decided by direct air-thermometer comparisons, such as are given in Table 18. There are three complete time series and two comparisons in steam.

The air-thermometer bulb used was my reentrant form, combined with the Jolly-Pfaundler stand, by a platinum capillary. The method of work is described elsewhere.[1] Here I need only remark that the metallic fiducial mark at the bulb end of the manometer, being nothing more than the sharpened end of the platinum capillary, the criterion of constant volume was given by an electric contact.

To heat the bulb I made use of a large paraffin bath, being a cylinder about 7 inches long and 7 inches in diameter. This was heavily jacketed with a thickness of about 1 inch of asbestos. At the center of the bath the bulb of the air thermometer was placed; and being of the reentrant form the junction of the thermocouple in its turn was at the center of the bulb.

The paraffin bath, Figs. 9 and 10, needs further description. It consists of two half cylindrical boxes of brazed copper, *d e f* and *g b k*, which fit into each other on their flat sides. These are of thin sheet copper, provided with hemispherical cavities *H* and gutters *t t* adapted to receive the air-thermometer bulb and thermocouple. The figure shows the thermocouple *α o β* and the air thermometer bulb *H H t* in place, the stem of the latter and the insulator of the former issuing in opposite directions. Though filled with paraffin in the present experiments, the apparatus was constructed to be used as a vapor bath at 210° (naphthalene) or 310° (diphenylamine). In such a case the chimneys *N* are prolonged by iron gas pipe into which the vapors distill and condense, falling back into the charge below (indicated by the dotted horizontal line). In this way thoroughly constant temperature may be obtained, and the apparatus is therefore available for standardizing[2] a porce-

[1] Bull. U. S. Geol. Surv., No. 54, 1889, pp. 168 et seq., 188 et seq.

[2] Cf. Barus: Bull. U. S. Geol. Surv., No. 54, 1889, pp. 22, 208 et seq.

Digitized by Google

lain (noninglazed) air thermometer, by aid of a glass air thermometer bulb of known constants, through the intervention of (or consecutive comparison with) the same platinum-iridium thermocouple.

In all cases the bath is to be heavily jacketed with asbestos, to a thickness of say 1 inch. Two burners are then sufficient.

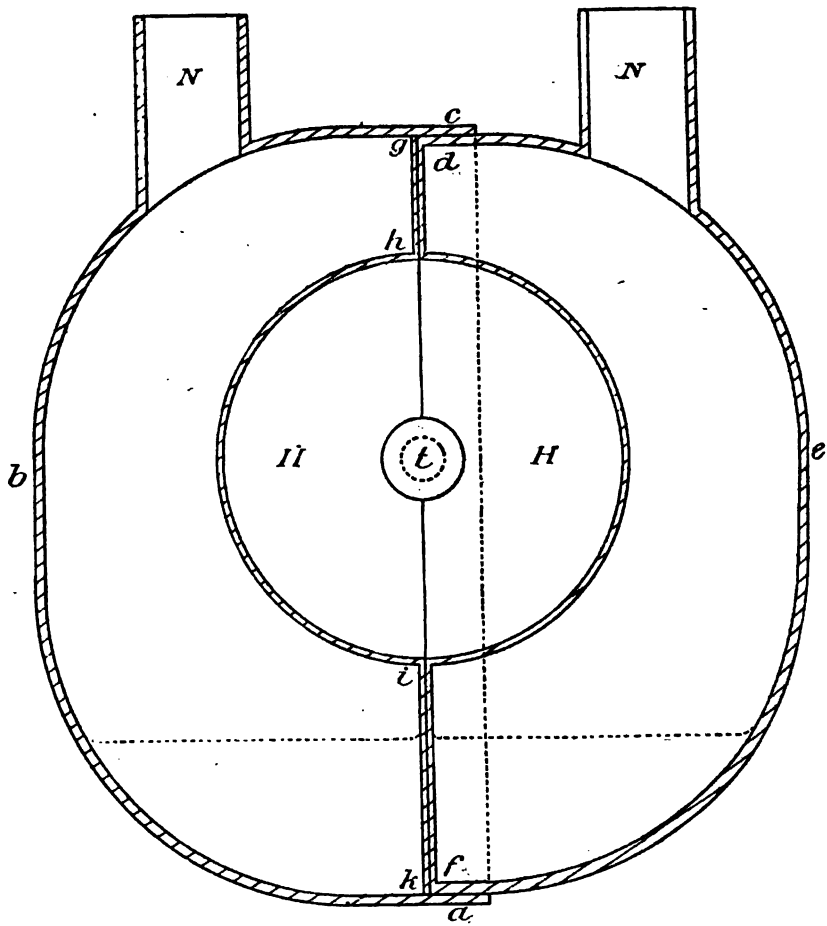


FIG. 9.—Sectional vapor bath, for comparing air thermometer and thermocouple.

50. *Observations.*—Observations were made during the period of cooling, after heating the bath to 300°; cooling must, therefore, take place so slowly that the temperature of the air thermometer bulb and of the thermocouple may be regarded as identical. Whether this is the case can be decided only by trial. Therefore, in making the following comparisons, the first and third series were observed during ordinary cooling; in the fifth series, however, a flat evaporating burner was placed under the paraffin bath to insure slower cooling. The liquid was stirred and paraffin gradually added to compensate for the contraction in cool-

Digitized by Google

ing. In the table V is the volume of the air-thermometer bulb, v' that of the hot part of the stem, v'' that of the cold stem and of the capillary connections and dead spaces; finally h_0 is the observed pressure for the bulb in melting ice. It is advisable to work with slightly rarefied air, to avoid pressure on the bulb at the high temperatures.

N'_{20} is the twist observed at the torsion galvanometer at the time given, and when the temperature measured by the air thermometer was $T_{a,t}$. From this I computed N_{20}, the twist which would have been ob-

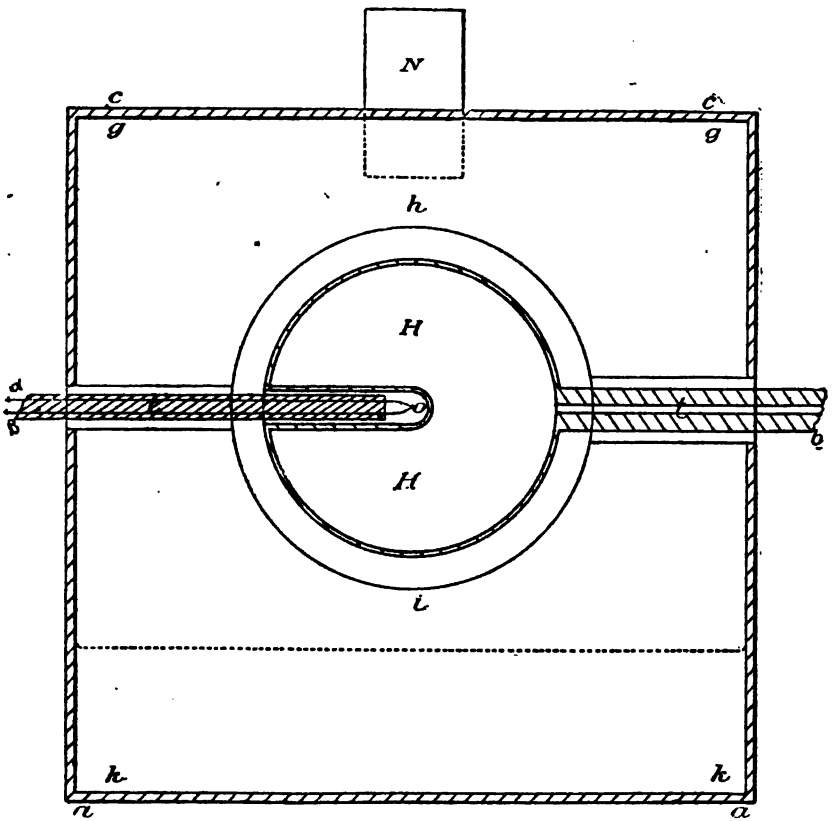


FIG. 10.—Longitudinal elevation of one of the halves of vapor bath, showing the thermometers in place.

served on the day of calibration (May 27), by the method shown in § 48. Hence I made use of the series II and V (comparisons in steam) and of the *low temperature* comparisons between thermocouple and air thermometer, for here the cooling is so slow that no time lag need be apprehended.

From both N'_θ and N_θ, the thermoelectric temperature equivalents $T_{t,c}$ and $T_{t,c}$ were then computed, by aid of the data of Table 17.

Digitized by Google

TABLE 18.—*Comparison of thermocouple and air thermometer.*

V=239·93^{cc}; v'=·030^{cc}; v''=.694^{cc}; h_c=48·29^{cm}.

Time.	N'_{20}.	T_{at}.	N_{20}.	T_{tc}.	Diff.	T_{tc}.	Diff.
I. 21	28·464	292·1	28·749	291·6	+ ·5	294·0	=1·9
36	25·531	263·5	25·786	267·8	−4·3	270·0	−6·5
44	24·001	251·4	24·241	255·1	−3·7	257·3	−5·9
52	22·648	239·4	22·874	243·6	−4·2	245·6	−6·2
61	20·456	222.1	20·660	224·6	−2·5	226·5	−4·4
7	19·438	213·3	19·632	215·5	−2·2	217.4	−4·1
18	18·052	201·3	18·233	203·1	−1·8	204·7	−3·4
34	16·066	183·2	16·227	185·2	−2·0	186.5	−3·3
45	14·893	171·2	15·042	174·2	−3·0	175·6	−4·4
58	13·571	160·6	13·707	161·8	−1·2	163·2	−2·6
17	12·155	146·9	12·277	148·5	−1·6	149·7	−2·8
34	10·840	134·9	10 948	135·4	− ·5	136·7	−1·8
50	9·912	125·5	10·011	126·4	− ·9	127·4	−1·9
12	8·639	114·0	8·725	113·6	+ ·4	114·5	− ·5
35	7·598	103·8	7·674	103·1	+ ·7	103·8	± ·0
9	6·359	90·4	6·423	90·3	+ ·1	91·0	− ·6
40	5·448	80·9	5·502	80·5	+ ·4	81·1	− ·3
58	4·975	76·4	5·025	75·4	+1·0	76·0	+ ·4
19	4·479	70·9	4·524	70·0	+ ·9	70·5	+ ·4
39	4·075	66·7	4·116	65·7	+1·0	66·1	+ ·6
II. 0	7·245	100·22	7·317	99·4	+ ·8	100·2	± ·0
20	7·264	100·28	7·337	99·6	+ ·7	100·4	− ·1
III. 34	28·174	286.3	28·456	289·4	−3·1	291·6	−5·3
45	26·136	270·0	26·397	272·8	−2·8	275·0	−5·0
56	24·400	255·0	24·644	258·5	−3·5	260·5	−5·5
7	22·050	235·3	22·270	238·5	−3·2	240·5	−5·2
17	20·731	224·3	20·938	227·0	−2·7	229·0	−4·7
26	19·338	214·5	19·531	214.6	− .1	216·6	−2·1
38	18·036	200·4	18·216	203.0	−2·6	204·8	−4·4
50	16·799	189·2	16·967	192·0	−2·8	193·6	−4·4
6	15·184	176·2	15·336	177·0	− ·8	178·5	−2·3
21	13·899	164·2	14·038	165·0	− ·8	166·4	−2·2
44	12·237	148·9	12 359	149·3	− ·4	150·4	−1·5
IV. 53	29·702	299·6	30·147	301·6	−2·0	305·0	−5·4
5	29·223	295·3	29·661	297·9	−2·6	301·2	−5·9
16	28·744	292·0	29·175	294·0	−2·0	297·3	−5·3
25	28·410	289·1	28·836	291·4	−2·3	294·8	−5·7
33	22·025	236·3	22·355	238·3	−2·0	241·2	−4·9
42	21·492	232·2	21·814	233·6	−1·4	236·5	−4·3
55	20·866	226·9	21·179	228·3	−1·4	231·0	−4·1
9	20·293	222·0	20·597	223·2	−1·2	225·8	−3·8
3	14·334	167·7	14·549	169·0	−1·3	171·2	−3·5
13	13·590	160·9	13·794	162·0	−1·1	164·1	−3·2
24	12·720	153·4	12·911	154·0	− ·6	155·6	−2·2
36	11·897	145·4	12·076	145·9	− ·5	147·7	−2·3
18	9·487	122·5	9·629	122·0	+ ·5	123·4	− ·9
29	8·943	117·2	9·077	116·7	+ ·5	118·0	− ·8
38	8·567	113·1	8·696	113·0	+ ·1	114·3	−1·2
52	7·966	107·1	8·086	106·7	+ ·4	108·0	− ·9
V. 20	6·618	94·0	6·717	93·0	+1·0	94·0	± ·0
†39	6·335	90·9	6·430	90·0	+ ·9	91·0	+ ·1
16	7·205	100·03	7·313	99·0	+1·0	100·1	− ·1
†28	7·221	100·09	7·329	99·1	+1·0	100·3	− ·2
37	7·199	100·09	7·307	99·0	+1·1	100·1	± ·0

* Steam. temperature 100·11°
† Steam temperature 99·93°.

TABLE 19.—*Interpolated from the above.*

T_{20} (air thermometer).	50°	100°	150°	200°	250°	300°
N_{20}	2·63	7·30	12·47	18·05	23·90	30·20

Digitized by Google

Tables 17 and 18, or a graphic representation, show at once that throughout every stage of cooling, temperature as registered by the thermocouple is always higher than the corresponding temperature of the air thermometer. Inasmuch as the system cools from the *outside* of the air thermometer bulb, this is precisely what must occur in case of too rapid cooling. It is well, however, to note that in Table 18, series IV, notwithstanding much retarded cooling, the discrepancy between air thermometer and thermocouple retains its original magnitude. Without passing judgment, therefore, I have deduced $T_a'_t$ and N_{20} from all the observations, for use below. See Table 19.

51. *Isometrics corrected as to temperature.*—Applying the corrected temperatures investigated in the foregoing paragraph, I obtained the following data for the isometrics. N_θ is the corrected twist and $\theta_a'_t$ and θ_{tc} its thermal equivalent, as expressed by the air thermometer or the thermocouple (boiling points, H_2O and Hg), respectively. The two data given under $\Delta\,\theta$ are to be similarly interpreted. Δp is the value already met in tables 12 to 16.

It follows from the slight irregularities still observable in the boiling points, that in order to use the torsion galvanometer satisfactorily, check measurements of the boiling point of water must be made before and after any series of temperature observations.

TABLE 20.—*Isometrics of ether.*

N_θ.	$\theta_{t,c}$.	$\theta_{a,a}$.	$\Delta\theta$.	Δp.	N_θ.	$\theta_{t,c}$.	$\theta_{a,t}$.	$\Delta\theta$.	Δp.
.....	15·1	15·1	0	0	15·566	180·6	178·6	164·4	1442
4·249	67·5	68·2	52·4	474				162·4	
			53·1		.....	16·2	16·2	0	0
4·273	67·8	68·4	52·3	479					
			52·9		.....	15·9	15·9	0	0
.....	15·5	15·5	0	0	16·245	186·9	184·5	171·0	1472
7·291	99·9	99·9	84·4	762				168·6	
			84·4		16·315	187·5	185·4	171·6	1468
7·309	100·1	100·1	84·6	765				169·5	
			84·6		16·405	188·4	186·2	172·6	1460
.....	15·5	15·5	0	0				170.4	
.....	15·4	15·4	0	0	.....	15·8	15·8	0	0
13·301	159·4	158·1	144·0	1272	7·308	100·1	100·1	84·3	767
			142·7					84·3	
13·412	160·5	159·2	145·0	1278	7·293	99·9	99·9	84·0	768
			143·7					84·0	
.....	15·5	15·5	0	0	.....	15·9	15·9	0	0
7·318	100·2	100·2	84·7	778					
			84·7		.....	16·0	16·0	0	0
7·282	99·8	99·8	84·5	778	7·300	100·0	100·0	84·0	783
			84·5					84·0	
4·260	67·7	68·4	52·4	493	7·300	100·0	100·0	84·0	784
			53·1					84·0	
4·260	67·7	68·5	52·7	493					
			53·5		.....	16·0	16·0	0	0
.....	15·0	15·0	0	0	7·294	99·9	99·9	83·9	767
.....	15·9	15·9	0	0				83·9	
7·312	100·1	100·1	84·2	755	7·287	100·0	100·0	84·0	770
			84·2					84·0	
7·288	99·9	99·9	84·0	757	4·287	68·1	68·5	52·0	491
			84·0					52·4	
					4·296	68·2	68·6	52·0	493
.....	16·2	16·2	0	0				52·4	
15·513	180·1	178·0	163·9	1439	.....	16·2	16·2	0	0
			161·8						

Digitized by Google

TABLE 20.—*Isometrics of ether*—Continued.

N_θ.	$\theta_{t,c.}$	$\theta_{a,t.}$	$\Delta\theta$.	Δp.	N_θ.	$\theta_{t,c.}$	$\theta_{a,t.}$	$\Delta\theta$.	Δp.
.....	16·4	16·4	0	0	4·351	68·6	69·4	51·0	439
7·294	99·9	99·9	83·5	781				51·8	
			83·5		4·359	68·6	69·5	51·0	440
7·285	100·0	99·9	83·6	783				51·9	
			83·5		7·267	99·7	99·7	82·0	706
20·177	222·0	219·0	205·6	1763				82·0	
			202·6		7·272	99·7	99·7	82·0	707
20·179	222·1	219·0	205·7	1760				82·0	
			202·6		.....	17·7	17·7	0	0
					13·320	159·6	158·2	141·9	1191
.....	16·5	16·5	0	0				140·5	
4·251	67·5	68·2	51·0	509	13·308	159·6	158·1	141·8	1171
			51·7					140·3	
4·284	67·9	68·5	51·4	515	.....	17·8	17·8	0	0
			52·0						
7·284	99·8	99·8	83·1	822	20·138	221·8	218·5	204·0	1639
			83·1					200·7	
7·313	100·1	100·1	83·4	824	20·146	222·0	218·7	204·1	1611
			83·4					200·8	
.....	16·7	16·7	0	0	.....	17·9	17·9	0	0
.....	16·6	16·6	0	0	.....	17·8	17·9	0	0
7·308	100·1	100·1	83·5	740	7·274	99·7	99·7	81·9	712
			83·5					81·9	
7·331	100·3	100·3	83·8	742	7·267	99·7	99·7	81·7	701
			83·8					81·7	
.....	16·5	16·5	0	0	.....	18·0	18·0	0	0
					20·290	223·1	219·9	205·1	1643
.....	16·6	16·6	0	0				201·9	
4·346	68·6	69·2	52·0	465	20·291	223·1	219·9	205·0	1619
			52·6					201·8	
4·334	68·5	69·1	51·9	467	.....	18·1	18·1	0	0
			52·5		4·350	68·6	69·2	50·5	437
7·325	100·2	100·2	83·6	745				51·1	
			83·6		4·361	68·6	69·5	50·5	437
7·314	100·1	100·1	83·5	747				51·4	
			83·5		.....	(18·1)	(18·1)	0	0
.....	16·6	16·6	0	0	13·420	160·4	159·2	142·3	1202
								141·1	
.....	16·6	16·6	0	0	13·437	160·5	159·4	142·7	1196
4·342	68·5	69·2	51·9	463				141·5	
			52·6		.....	17·9	17·9	0	0
4·355	68·7	69·4	52·1	464					
			52·8		.....	17·4	17·4	0	0
7·295	99·9	99·9	83·3	739	20·216	222·4	219·2	205·0	1644
			83·3					201·8	
7·323	100·2	100·2	83·6	743	20·198	222·3	219·0	204·9	1642
			83·6					201·6	
.....	16·6	16·6	0	0	.....	17·4	17·4	0	0
13·230	158·8	157·4	142·2	1289	7·324	100·2	100·2	82·8	729
			140·8					82·8	
13·356	160·0	158·7	143·3	1208	7·277	99·8	99·8	82·4	723
			142·0					82·4	
.....	16·7	16·7	0	0	.....	17·4	17·4	0	0
16·009	184·9	182·7	168·2	1370	4·450	69·8	70·2	52·4	464
			166·0					52·8	
16·021	185·0	182·8	168·3	1369	4·468	69·9	70·4	52·5	464
			166·1					53·0	
.....	16·7	16·7	0	0	.....	17·4	17·4	0	0
					13·308	159·5	158·1	142·1	1220
								140·7	
					13·340	159·7	158·4	142·1	1209
								141·0	
.....	17·6	17·6	0	0	.....	17·4	17·4	0	0

Digitized by Google

TABLE 21.—*Isometrics of alcohol.*

N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp	N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp
.....	17·2	17·2	0	0	7·823	100·2	100·2	83·4	833
4·493	70·1	70·6	52·9	562				83·4	
			53·4		.....	16·8	16·8	0	0
4·499	70·2	70·9	53·0	556	13·520	161·4	160·0	144·6	1592
			53·7					143·2	
.....	17·2	17·2	0	0	13·522	161·4	160·0	144·5	1582
7·317	100·2	100·2	83·0	891				143·1	
			83·0		.....	16·9	16·9	0	0
			83·0		.....	16·9	16·9	0	0
7·323	100·2	100·2	83·0	888	4·310	68·2	68·9	51·2	541
.....	17·2	17·2	0	0				52·0	
13·464	160·8	159·6	143·6	1583	4·300	68·1	68·8	51·1	533
			142·4					51·8	
			143·6		.....	17·0	17·0	0	0
13·461	160·8	159·6	142·4	1575	7·345	100·4	100·4	83·4	895
.....	17·2	17·2	0	0				83·4	
.....	17·0	17·0	0	0	7·316	100·2	100·2	83·2	884
7·837	100·4	100·4	83·4	899	.....	17·0	17·0	83·2	
			83·4					0	0

TABLE 22.—*Isometrics of thymol.*

N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp	N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp
4·273	67·7	68·5	50·5	704	9·763	124·8	124·5	107·6	1495
			51·3					107·3	
4·308	68·2	68·9	51·0	705	.....	17·2	17·2	0	0
			51·7		.....	17·0	17·0	0	0
7·305	100·0	100·1	82·8	1155	4·339	68·5	69·1	51·5	721
			82·9					52·1	
7·289	99·9	99·9	82·7	1156	4·325	68·4	69·0	51·5	729
			82·7					52·1	
4·356	68·8	69·2	51·6	714	.....	16·9	16·9	0	0
			52·0		7·307	100·1	100·1	83·2	1166
4·398	69·2	69·8	52·0	715				83·2	
			52·6		7·334	100·3	100·3	83·5	1171
.....	17·2	17·2	0	0				83·5	
7·303	100·0	100·0	82·8	1169	.....	16·8	16·8	0	0
			82·8		9·889	126·1	125·8	109·3	1512
7·303	100·0	100·0	82·8	1160				109·0	
			82·8		9·963	126·9	126·5	110·1	1506
.....	17·2	17·2	0	0				109·7	
9·769	124·9	124·6	107·7	1508	.....	16·8	16·8	0	0
			107·4						

About a month later, and after the gauge and appurtenances had been much used during intervening experiments, I repeated the work for thymol again, using the same tube as in Table 22. The results are given in the next table (22 supplement) and will be seen to be in excellent accord with the earlier data. This proves that there can have been no error in the method of measurement between times, and hence the exceptional behaviors noted in case of some of the following substances are actual peculiarities. The constancy of the gauge factors vouched for in this way is gratifying.

TABLE 22 (supplement).—*Isometrics of thymol. Check-work a month after the above.*

N'_θ	t	$n\theta$	$N\theta$	θ	N_p	p	$\Delta\theta$	Δp
.....	.....	.....	.....	25·9	6·20	170	0	0
6·513	27·6	·665	7·188	100·0	44·47	1218	74·1	10·48
6·460	27·7	·673	.....	100·0	44·50	1219	74·0	10·38
.....	.....	.....	.....	26·0	6·60	181	0	0
8·896	28·1	·711	9·607	125·1	57·25	1569	99·1	13·88
8·925	28·1	·711	9·636	125·5	57·25	1569	99·5	13·90
.....	.....	.....	.....	26·0	6·55	179	0	0

Digitized by Google

TABLE 23.—*Isometrics of para-toluidine.*

N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp	N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp
4·328	68·4	69·1	.....	.....	9·776	125·0	124·8	56·7	799
4·311	68·2	68·9	0	0				55·9	
7·286	99·9	99·9	31·7	452	4·307	68·3	68·9	0	0
			31·0		4·336	68·5	69·2	0	0
7·274	99·7	99·7	31·1	441	13·231	158·8	157·4	90·3	1137
			30·4					88·2	
4·352	68·6	69·3	0	0	13·256	159·0	157·8	90·5	1124
4·343	68·5	69·2	0	0				88·8	
9·774	124·8	124·6	56·3	809	4·332	68·5	69·0	0	0
			55·4		4·331	68·5	69.0	0	0

TABLE 24.—*Isometrics of diphenylamine.*

N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp	N_θ	$\theta_{t,c}$	$\theta_{a,t}$	$\Delta\theta$	Δp
4·323	68·3	69·0	.....	.....	13·731	163·4	162·2	94·4	1345
4·315	68·2	69·0	0	0				92·6	
7·303	100·0	100·0	31·8	499	4·392	69·0	69·6	0	0
			31·0		4·398	69;2	69·8	0	0
7·297	100.0	100·0	30·8	487	7·284	99·9	99·8	30·7	481
			30·2					30·0	
4·399	69.2	69·8	0	0	7·316	100.2	100·2	30·7	479
4·407	69·4	69·9	0	0				30·1	
9·916	126·5	126·0	57·1	915	.....	(69·5)	(70·1)	.....	.....
			56·1		4·428	69·5	70·1	0	0
9·978	127·0	126·6	58·3	900	4·455	69·7	70·5	0	0
			57·2		9·988	127·1	126·8	57·4	914
4·360	68·7	69·4	0	0				56·3	
4·366	68·8	69·6	0	0	10·053	127·6	127·3	57·6	904
								56·5	
					4·479	70·0	70·8	0	0
13·752	163·7	162·4	94·7	1346	4·456	69·8	70·6	0	0
			92·8						

CORRECTION FOR THE THERMAL AND ELASTIC VOLUME CHANGES OF THE GLASS TUBES.

52. *Thermal expansion of glass.*—The direct measurement of the elastic constants of glass throughout an interval of 300° and 2000 atmospheres is at present out of the question. Hence I selected liquid substances of large compressibility, in order that the discrepancies due to the compressibility of glass might be of smaller magnitude, and could, therefore, be at least in a measure applied by interpolation from known data. It is clear at the outset, moreover, that the correction in question is of smaller moment, because it is differential in character. Rise of temperature expands the glass tube, pressure again diminishes it. If the isometrics of solid glass and the liquids were identical, the correction would be nil. Curiously enough this is nearly the case.

The expansion of glass throughout large intervals of temperature was measured by Dulong and Petit,[1] by Recknagel,[2] and by others. The results of the latter are the larger. For this reason I accept the former, seeing that in the case of compressibility of glass a datum

[1] Dulong and Petit: Ann. de chim. et phys. (2), VII. 1817, p. 113.
[2] Recknagel: Sitz. Ber. k. Bayr. Acad. (2), 1866, p. 327.

Digitized by Google

too small must be accepted for want of data on the thermal variations. Dulong and Petit find that from—

$0°$ to $100°$, coefficient of expansion, $\beta = 258/10^7$
$0°$ to $200°$, coefficient of expansion, $\beta = 276/10^7$
$0°$ to $300°$, coefficient of expansion, $\beta = 304/10^7$.

A chart may then be platted from which β may be taken for any interval. It follows that the volumes, V_{20} of the constant volume tube, in terms of the volume at $20°$, will be (pressure = 1 atmosphere).

T =	$20°$	$50°$	$100°$	$150°$	$200°$	$250°$	$300°$
V_{20}=	1·00000	1·00075	1·00208	1·00350	1·00504	1·00670	1·00856

Again, the corresponding volumes, V_{70} in terms of the volume at $70°$, will be—

T =	$70°$	$100°$	$150°$	$200°$
V_{70} =	1·00000	1·00080	1·00222	1·00376

53. *Compressibility of glass.*—On the other hand the compressibility of glass, $1/k$, from corroborative results of Regnault and Amagat[1], is $1/4\times10^{11}$ in terms of dynes and square centimeters. Bearing in mind, therefore, that no compensation of k in respect to temperature can be made, the volumes of the constant volume tube under any hydrostatic pressure, P will be $1 - P \times 10^6/k$, where

P =	500	1000	1500	2000	2500	3000 atmospheres,
P/k =	·00125	·00250	·00375	·00500	·00625	.00750

Thus, when the initial temperature is $20°$, the volumes will be as follows:

TABLE 25.—*Isometrics of solid glass, in terms of unit of volume at 20° and 1 atmosphere.*

Θ =	20°	50°	100°	150°	200°	250°	300°
P = 1 atm.	1·0000	1·0007	1·0021	1·0035	1·0050	1·0067	1·0086
500 atm.	·9987	·9995	1·0008	1·0022	1·0030	1·0054	1·0073
1000 atm.	·9975	.9982	·9996	1·0010	1·0025	1·0042	1·0061
1500 atm.	·9962	·9970	·9983	·9997	1·0013	1·0029	1.0048
2000 atm.	·9950	·9957	·9971	·9985	1·0000	1·0017	1·0036
2500 atm.	·9937	·9945	·9958	·9972	·9988	1.0004	1·0023
3000 atm.	·9925	·9932	·9946	·9960	·9975	·9992	1.0011

A similar table is easily constructed for unit of volume at $70°$ and 1 atmosphere.

If these results are represented graphically, the volume changes δv, if the constant volume tubes can be at once obtained for each of the pairs of values of $\Delta\theta$ and Δp given in tables 20 to 24. I have given a full list of the values, δv, in table 27, where the arrangement adopted is such as to correspond to the earlier tables (12 to 16).

54. *Compressibility of the above liquids.*—Having given these data, it is therefore finally necessary to find the pressure equivalent of the

[1] Amagat: C. R., CVIII, 1889, p. 1199; CVII, 1888, p. 618, or J. D. Everett's Tables (Macmillan, 1879, p. 53).

Digitized by Google

values δv; in other words, to find the value δp which will annul δv. To do this it is necessary to know the compressibility of each of the liquids under the given conditions of pressure and temperature. The results of my earlier papers[1] are available for this purpose, and from them I take the following mean values.

TABLE 26.—*Correction factors* $\left(d\left(\frac{v}{V}\right)/dp\right)_{\theta p}$, *being compressibilities at* $\theta°$ *and* p *atm.*

ETHER. $\Delta\theta = \theta - 20°$.		
θ	$10^6 d\left(\frac{v}{V}\right)/dp$	p
°		
70	100	600
100	95	830
160	80	1340
185	70	1400
220	60	1760
ALCOHOL. $\Delta\theta = \theta - 20°$.		
°		
70	66	700
100	63	1040
160	51	1730
PARATOLUIDINE. $\Delta\theta = \theta - 70°$.		
100	52	870
136	50	1240
160	45	1580

THYMOL. $\Delta\theta = \theta - 20°$.		
θ	$10^6 \times d\left(\frac{v}{V}\right)/dp$	p
°		
70	46	910
100	44	1360
130	42	1710
DIPHENYLAMINE. $\theta\Delta = \theta - 60°$.		
θ	$10^6 \times d\left(\frac{v}{V}\right)/dp$	p
100	42	960
130	40	1390
160	38	1780

Knowing therefore the volume changes of the glass, and the compressibility of the inclosed liquid under the given conditions of pressure and temperature, the correcton δp follows by division. This is fully given in Table 27. Utilizing these values I constructed the final Table 28, in which $\Delta\theta$ and Δp, such as would be observed if the glass tube were absolutely rigid, are inserted. This table 28 exhibits the importance of the correction δp, relative to Δp. For $\Delta\theta$ I give the thermoelectric values only, believing them to be the more nearly correct. The table also contains p_o and θ_o, which are the initial pressures and temperatures used in constructing Δp and $\Delta\theta$ (cf. Tables 12 to 16). In case of paratoluidine and diphenylamine, p_o had to be estimated.

[1] Barus: Am. Journ. (3), XXXIX, 1890, p. 501.

Digitized by Google

TABLE 27.—*Corrections (δp) for thermal and elastic volume changes of glass tubes.*

ETHER.

Δp	$\Delta\theta$	$\delta v \times 10^6$	$10^6 \times d\left(\frac{v}{V}\right)/dp$.	δp	$\Delta p, p$	$\Delta\theta$	$\delta v \times 10^6$	$10^6 \times d\left(\frac{v}{V}\right)/dp$	δp
475	52	+ 100	110	+ 1	740	84	+ 350	95	+ 4
765	84	+ 300	95	3					
					465	52	+ 200	110	2
1275	144	+ 700	80	9	750	84	+ 300	95	3
780	85	+ 300	95	3	465	53	+ 150	110	1
495	53	+ 100	110	1	740	84	+ 300	95	3
					1250	142	+ 600	80	7
					1370	167	+ 1150	70	16
755	84	+ 300	95	3					
1440	164	+ 900	70	13					
					490	52	+ 250	100	2
					760	82	+ 400	95	4
1470	170	+ 1080	70	15	1250	141	+ 900	80	11
765	84	+ 280	95	3	1710	202	+ 1800	60	30
785	84	+ 300	95	3	816	82	+ 400	95	4
					1760	203	+ 1750	60	30
					580	51	+ 200	100	2
770	84	+ 300	95	3	1344	142	+ 800	80	10
490	52	+ 100	110	1					
					1760	203	+ 1700	60	+ 28
780	84	+ 300	95	3	850	83	+ 350	95	+ 4
1760	204	+ 1400	60	23	590	53	+ 200	100	+ 2
					1340	141	+ 800	80	+ 10
510	52	+ 0	110	0					
820	83	+ 100	95	1					

ALCOHOL.

700	53	— 100	66	— 2	1730	144	— 100	51	— 2
1030	83	— 50	63	— 1	690	52	— 00	66	— 0
1730	143	— 100	51	— 2	1050	83	— 50	63	— 1
1030	83	— 100	63	— 2					

PARATOLUIDINE.

870	31	— 300	52	— 6	1580	89	— 300	45	— 7
1240	56	— 410	50	— 8					

THYMOL.

900	51	— 500	46	— 11	1710	108	— 950	42	— 23
1350	83	— 750	44	— 17	930	52	— 500	46	— 11
910	52	— 500	46	— 11	1370	83	— 750	44	— 17
1360	85	— 750	44	— 17	1715	110	— 850	42	— 20

DIPHENYLAMINE.

1000	31	— 450	43	— 10	920	30	— 400	43	— 9
1430	58	— 650	40	— 16	1350	57	— 700	40	— 18
1780	93	— 800	38	— 21					

Digitized by Google

TABLE 28.—*Isometrics—Digest of probable results corrected.*

Substance.	$\Delta\theta$	$\frac{\Delta p'}{\delta p'}$	Δp	Substance.	$\Delta\theta$	$\frac{\Delta p'}{\delta p'}$	Δp
Ether.....	50·5	437	439	*Paratoluidine	31·4	441	435
		2				—6	
$\theta_0 = 18°$	81·8	701	705		56·5	800	792
		4				—8	
$p_0 = 30$ atm ...	142·5	1196	1206	$\theta_0 = 68°$	90·4	1124	1117
		10				—7	
	205·0	1619	1649				
		30		Thymol.....	51·3	710	700
						—11	
Ether.....	52·5	464	466	$\theta_0 = 17°$	82·7	1158	1141
		2				—17	
	82·6	723	727	$p_0 = 80$ atm ...	107·7	1495	1472
		4				—23	
$\theta_0 = 17°$	142.1	1209	1219				
		10		Thymol.....	51·5	729	718
$p_0 = 30$ atm ...	205·0	1642	1670			—11	
		28		$\theta_0 = 17°$	83·6	1171	1154
						—17	
Alcohol.....	53·0	556	554	$p_0 = 80$ atm ...	109·7	1506	1486
		—2				—20	
$\theta_0 = 17°$	83·0	888	887				
		—1		*Diphenylamine.....	31·3	487	477
$p_0 = 50$ atm ...	143·6	1575	1573			—10	
		—2		$\theta_0 = 68°$	57·7	900	884
						—16	
Alcohol.....	51·2	533	551				
		—2		*Diphenylamine.....	30·7	479	469
$\theta_0 = 17°$	83·4	889	888			—10	
		—1			57·5	904	896
$p_0 = 50$ atm ...	144·5	1582	1580			—18	
		—2		$\theta = 68°$.....	94·5	1345	1324
						—21	

* $p_0 = 400$ atm., approximately.

DEDUCTIONS.

55. *Curvature and slope of the isometrics.*—The deductions to be made from the above laborious investigation can be briefly stated. It conduces to clearness to express graphically both the data of Tables 20 to 24, as yet uncorrected for the volume changes of the glass tube containing the solutions, as well as the data of Table 28, in which this correction has been provisionally added. This is done in Pl. II, 1 and 2, in both of which Δp are fully given, as is also $\Delta\theta$ in 1. In 2 the change of $\Delta\theta$ is represented, and the points are connected by straight lines to bring out the contour of the curves.

It is seen at a glance that below 1,000 atmospheres the curves are so nearly linear that they may be accepted as such with an error no larger than 1° or 2° at 1,000 atmospheres. This is quite within the unavoidable errors, as may be seen from an inspection of the individual points. The discrepancy is somewhat greater for toluidine[1]; here, however, the initial temperature is high, being 70°.

Turning first (Pl. II, 1) to ether, the deviation from the right line at 1000 is less than 1° C.; at 1500 atmospheres, the deviation is 9·5° in one case and 10° in the other, showing an abrupt increase of curvature. The slopes of the isometric within the first 1000 atmospheres, are

[1] Owing to breakage of the tube, I did not repeat toluidine.

Digitized by Google

Digitized by Google

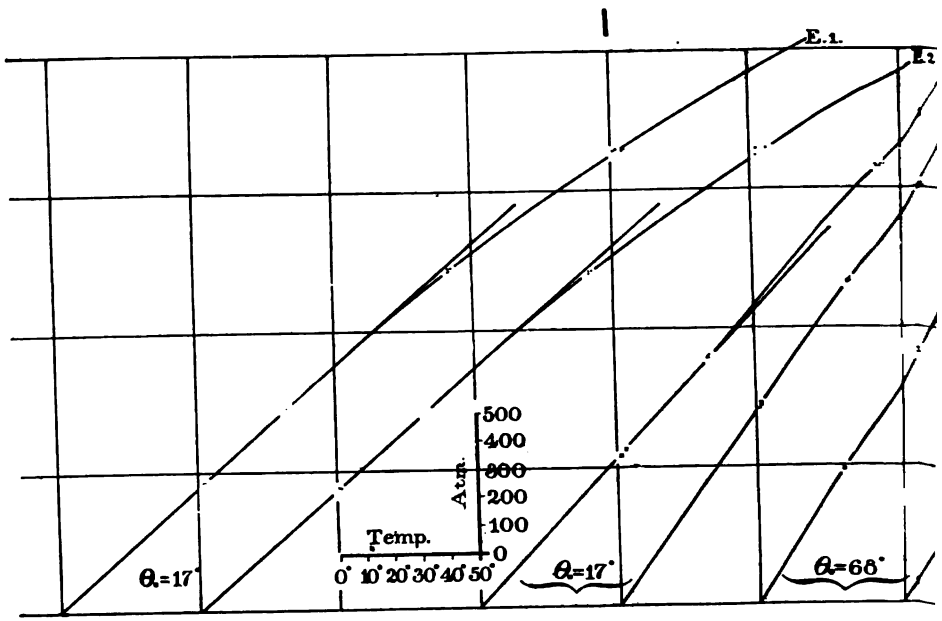
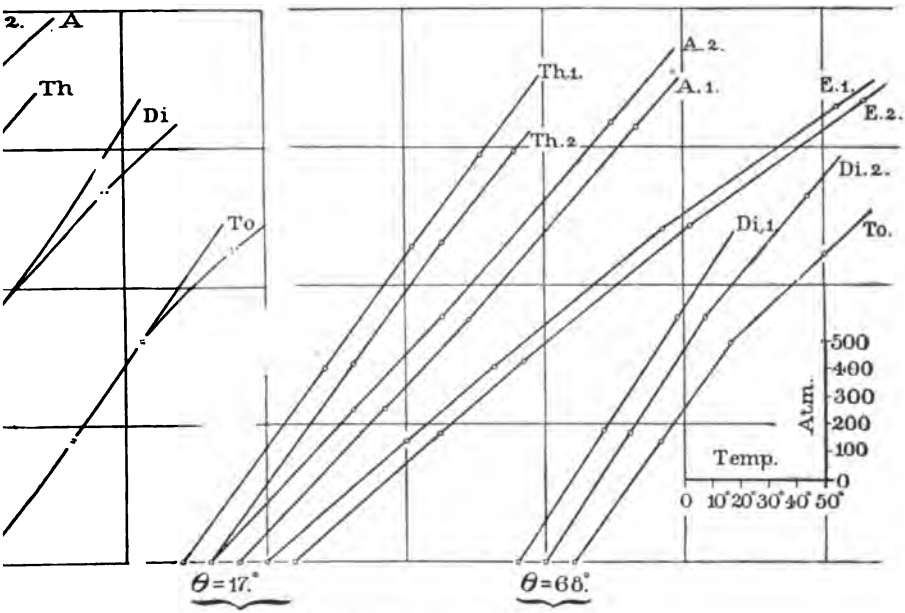


DIAGRAM SHOWING THE ISOMETRICS OF ETHER, ALCOHO

Digitized by Google

2



IOL, THYMOL, PARATOLUIDINE AND DIPHENYLAMINE.

Digitized by Google

Digitized by Google

1°/1000=·114 in one case and 115/1000=·115° per atmosphere in e other.

Alcohol differs from all the other isometrics, inasmuch as the curva- e is upward. The deviation at 1000 atmospheres is nearly 2°. The tial slope of the isometric 95°/1000=·095° per atmosphere.

Thymol, curiously enough, is strikingly near a straight line. The riation at 1000 is inappreciable. The slope of the isometric 71/1000= 1° per atmosphere.

Diphenylamine deviates from the straight line. The slope is 63/1000= 3° per atmosphere.

n case of toluidine the slope is ·070° per atmospere. In the two ter cases it must be remembered that the initial temperature is 78°, l the initial pressure 400 atmospheres. The deviation from the rec- near path is an abrupt high-temperature occurrence.

'urning finally to pl. II, 2, the following slopes are found which may compared with the slope of 1:

TABLE 29.—*Observed initial slopes of the isometrics.*

	Ether.	Alcohol.	Thymol.	Diphenyla- mine.	Para-tolui- dine.
	°C. / atm.	°C. / atm.	°C. / atm.	°C. / atm.	°C. / atm.
Not corrected for volume changes of glass tubes	·114 ·115	·095	·071	·063	·070
Corrected for volume changes of glass tubes	·116 ·114	·095 ·094	·073 ·072	·065 ·065	·072
Initial temperature	17°	17°	17°	68°	68°
Initial pressure, atmosphere	80	50	80	(400)	(400)
Boiling point	34°	78°	233°	310°	198°
Melting point			53°	54°	43°

; is seen from this table, as well as from Table 28, that the correc- to be applied in consequence of nonrigidity of glass never exceeds r cent. In case of ether and alcohol it may be disregarded. In other cases the approximation made is probably warranted without orate measurements of the elastics of glass.

the abrupt change of curvature above 1000 atmospheres were due n unwarranted application of Hooke's law, the curvature of the ietrics would tend to change in similar ways for all curves at the e pressures. This is not the case for the above curves, in which the our of each preserves an individual character. Even after the gauge been strained (§ 42) I detected no differences in the factor. Again, repetition of the thymol work in Table 22 (supplement), made es- ılly to throw light on the present question, shows that no time : in the constants of the pressure apparatus is to be apprehended.

ıe slopes given in the last table have no absolute value, since these must vary with the initial volume under consideration. Volume ;urements are beyond the scope of the present paper. I may state, ;ver, that when volume measurements are included the complete nodynamics of liquid matter are expressible in the family of curves ined with a degree of accuracy which is experimentally the most se.

Digitized by Google

56. *Final interpretation.*—For the time being the above results admit of the following interpretation: Whenever a substance passes from the liquid to the gaseous state, no matter whether this takes place continuously above the critical temperature or discontinuously below it, the underlying cause is a change of molecule from a more complex to a less complex type. As long as the molecule remains unchanged the isometrics are straight. When the change of molecule takes place so as to begin with the liquid molecule and pass continuously into the gaseous molecule, the isometrics curve continuously for the linear isometric of the true liquid to that of the true gas. Such an explanation is of course tentative. It rests on evidence purely experimental and therefore of uncertain interpretation; and it is suggested by a controversy which I have summed up elsewhere[1] as follows: "The linear relation was predicted from theoretical considerations by Dupré (1869) and by Lévy (1884)—considerations soon proved to be inadequate by Massieu, H. F. Weber, Boltzmann, and Clausius. Ramsay and Young (1887) established[2] the relation in question experimentally for vapors, but not, I think, very fully for liquids decidedly below their critical points. Reasoning from these data, Fitzgerald (1887) investigated the consequences of the law, viz: (1) specific heat under constant volume is a temperature function only; (2) internal energy and entropy can be expressed as a sum of two terms, one of which is a volume function only and the other a temperature function only. Thus Ramsay, Young, and Fitzgerald arrive substantially at the same position from which Dupré and Lévy originally started."

However, too much care can not be taken in keeping clearly in mind that pressures which, in relation to the usual laboratory facilities, are exceptionally large, may yet be mere vanishing increments when mapped out on the scale of the molecular pressures of liquids and solids.

Some notion of the internal pressures encountered may be gained as follows:

Studying the compression of organic substances throughout an interval of 310° and 600 atmospheres, I found that the isothermal compression v/V could be well represented by an equation $v/V=\ln(1+\alpha p)^{1/\vartheta}$, where ϑ and α are constants and p denotes pressure. Taking this as a basis, I sought the mean values of the constants involved in some fifty-three isothermals, and found $-v/V=\ln(1+9\vartheta)^{1/9}$ to apply within the limits of error of my work. To this extent, therefore, compressibility increases as the reciprocal of the first power of the pressure binomial $(1/9\vartheta+p)$. The interpretation to be given to $1/9\vartheta$ is that of an initial or internal pressure. Computing its value for the above or organic liquids, I found the data of Table 30.

---

[1] Am. Jour., Sci. 3d ser., vol. 38, 1889, p. 407.

[2] For a pressure interval not exceeding about 80 atmospheres for a group of isometrics, nor about 30 atmospheres for a single isometric. See Ramsay and Young, Phil. Mag.: 5th ser., vol. 23, 1887, p. 45

Digitized by Google

TABLE 30.—*Order of values for internal pressure, assuming* $d\left(\frac{v}{V}\right) dp = \theta \mid (1 + 9\vartheta p)^2$

Subst.	θ	Internal pressure.	Subst.	θ	Internal pressure.
	°C.	*Atm.*		°C.	*Atm.*
Ether $p_0 = 100$.	29°	673	Para-toluidine $p_0 = 20$.	28°	1,852
	65°	491		65°	1,610
	100°	323		100°	1,262
	185°	110		185°	671
	310°	32		310°	263
Alcohol $p_0 =$ 150.....	28°	1,249	Diphenylamine $p_0 = 0$ ...	65°	1,709
	65°	967		100°	1,610
	100°	703		185°	1,010
	185°	336		310°	521
	310°	80			
Thymol.....	28°	1,683			
	64°	1,481			
	100°	1,146			
	185°	669			
	310°	228			

If, however, compressibility be supposed to vary as the square of the pressure binomial,[1] viz:

$$d\left(\frac{v}{V}\right) / dp = -\mu / (1 + \nu p)^2,$$

the internal pressures corresponding, will have about twice the above values. Now it appears, from recent experiments of my own, that the last expression is probably the more nearly true. It follows therefore that at zero centigrade, internal pressures of the order of 1,000 to 4,000 atmospheres are to be taken into account.

57. *Isometrics of solid glass.*—A singularly curious inference is suggested in comparing the approximate isometrics of glass above deduced, (§§ 52, 53), with the liquid isometrics of the present and earlier papers. It appears that for solid glass the slope of the isometric is about 100°/1000 = .1° per atmosphere in its initial course. This coincides very nearly with the slope of the isometrics of the above organic liquids, varying as they do between .07° and .12° per atmosphere. In view of the similarity of glass and the rock producing magma, this degree of isometric similarity is of great interest. In general the proximity of the solid and liquid isometric of compound matter is worthy of note.

The metallic isometrics are different from the above. So far as they can be obtained[2] the slope of the isometric

$$\frac{\theta}{p} = 10^6 \Big/ k\beta$$

per atmosphere, where k and β are respectively the resilience of volume and the coefficient of expansion, is only ·014° for steel, ·016° for

[1] Cf. Barus: Am. Journ. Sci. (3), vol. 39, 1890, pp. 497-506.

[2] Constants k and β are taken from Everett's tables.

Digitized by Google

iron, and ·011° for copper. They thus preserve an order of magnitude different from that of glass or the above organic liquids.

58. *Conclusion.*—In conclusion I will advert to the easy possibility of obtaining families of isometrics, and from them a complete representation of the isometrics of liquids with a given pressure interval of say. .3000 atmospheres. For this purpose it is merely necessary to change the volume of liquid contained in the glass tubes, and to refer all volumes to the one obtaining at the initial temperature. Thus in the above tube and in case of ether, temperatures pass from 20° to 220°, while pressure varies from 0 to 1,900 atmospheres, say. Suppose, now, that the electric contact is moved in such a way that at 200° the pressure producing contact is not much greater than the vapor tension of the liquid. Clearly, therefore, the isometrics may now be studied between 200° and a temperature between 300° and 400°, while pressure varies between 0 and 2,000 atmospheres as before, etc. Apart from the unavoidable tediousness of the work, the experimental devices suitable for accomplishing this easily suggest themselves.

Digitized by Google

CHAPTER III.

A COMPARISON OF THE BOURDON, THE TAIT, AND THE AMAGAT HIGH-PRESSURE GAUGES.

HISTORICAL.

59. *The earlier work.*—In my earlier work (chapter II), while investigating the isometrics of liquids, I was obliged to content myself with an investigation of empiric pressure gauges. I found by comparing different Tait gauges with a large Bourdon gauge that so long as pressure continually increased from zero, the relation between the indication of each under like conditions of pressure was linear; but that when pressure again decreased from the high value (1,000 atmospheres or more) to zero, this relation changed to a markedly curvilinear locus, of such a kind that eventually the original zero of both guages was regained. So long as increasing pressures alone were dealt with, either of these gauges could be used with safety. The present work, in which both gauges are directly compared with Amagat's manométre à pistons libres, corroborates this inference, and shows that the bow-shaped cycles[1] represent the actual motion of the free end of the Bourdon tube. From this point of view the present datea are important, for they supply an example of purely mechanical hysteresis, and possibly of metallic volume lag. The data also show that cyclic indications are absent in the steel Tait gauge, and that this instrument may be adopted for the scientific measurement of pressures of any value whatever.

60. *Amagat's manometer.*—The instrument in my possession[2] is constructed for the measurement of pressures as high as 3,000 atmospheres. At this extreme limit the height of the compensating column of mercury (the diameters of the two pistons being ·549^{cm} and 12·171^{cm} respectively) will be about 464^{cm}. To read so long a column with reasonable convenience, I fixed a long, painter's ladder in a vertical position, and permanently attached to one side of it both the open manometer tube and the long millimetre scale, which I ruled with care on a wide strip of brass. A round leather belt, passing from top to bottom of the ladder and everywhere within easy reach, passed over a pulley adjustment, and was suitably connected with the mechanism for rotating the two "pistons libres." In this way I was able to make this essential adjustment immediately before taking my reading, no matter what my position on the ladder might be.

[1] Phil. Mag., 5th ser., vol. 30, 1890, p. 338. Ibid., pl. x. In the paper cited I was of the opinion that the cycles were thermal phenomena to be sought for in the Tait gauge.

[2] Marked E. H. Amagat, Lyon, 1890.

Digitized by Google

I found by trial, that by using the thick mineral machine oil mentioned in my last paper[1], the manometer would be at once connected with my screw compressor, and that the charge of molasses was quite superfluous. I also floated the lower piston in this oil. Thus the same oily liquid for the transmission of pressure is used with advantage throughout the system of apparatus. Once put together, it is ready for use at all times and need not again be touched in years. Care of course must be taken to obtain oil free from grit or dust.

61. *The Bourdon gauge.*—The gauge used was the one to which my earlier measurements apply, having a tube of steel. I made two series of comparisons of this gauge with the manometer. In the first of these the usual Bourdon multiplying gear was used; in the other the excursions of the free end of the Bourdon tube were read off directly with a Fraunhofer microscopic micrometer after the multiplying gear had been detached. Of many experiments of this kin d which I made I will give the following typical examples contained in Tables 31 and 32. In Table 1 the Bourdon registry is given at once in atmospheres, the Amagat registry both in centimeters and in the atmospheres reduced therefrom. There are four series of observations, two of them within an interval of 500 atmospheres and the other two within 1,000 atmospheres. Two observations are made at each step of pressure. In Table 32 the micrometer position of the end of the Bourdon gauge is given in cm./40, this being the scale part of the Fraunhofer gauge. In other respects the data are given as in Table 31. Observations were made in triplets, two at the manometer including each one at the Bourdon gauge.

TABLE 31.—*Cyclic comparison of the Bourdon gauge (steel tube) with the Amagat manometer.—Multiplying gear.*

Bourdon.	Amagat.	Amagat.	Bourdon.	Amagat.	Amagat.	Bourdon.	Amagat.	Amagat.
Atm.	*Cm.*	*Atm.*	*Atm.*	*Cm.*	*Atm.*	*Atm.*	*Cm.*	*Atm.*
188	28·65	185	21	2·50	16	465	72·40	468
174	26·80	173	242	37·30	241	458	70.80	458
322	50.30	325	231	35·80	232	650	101·00	653
312	48.60	314	472	73·30	474	645	99·90	647
457	70·90	459	457	71·30	461	855	133·00	860
446	69·20	448	660	102·00	660	838	128·60	832
316	49·50	314	640	99·30	642	985	151·80	982
313	48·10	311	859	131·30	849	977	148·30	980
162	24·30	157	844	128·80	833	964	147·30	954
165	24·50	158	991	151·80	982	950	144·80	937
27	3·60	23	977	148·80	962	840	125.00	809
			847	126·00	815	834	123·90	802
29	3·70	24	837	124·20	804	631	90·80	587
172	26·30	170	651	93·60	606	626	90·00	583
168	25·50	165	646	92·90	601	440	59·60	386
317	49·10	318	475	65·10	421	440	59·60	386
305	47·30	306	475	64·90	420	260	33·30	215
462	71·80	464	262	34·50	223	264	34·40	222
444	69·10	447	263	34·70	225	35	3·30	21
433	67·20	435	28	2·50	16	35	3·80	25
224	33·90	219	28	2·70	17			
225	34·10	221						
83	12·10	78	30	2·90	19			
84	12·10	78	251	38·60	250			
20	2·50	16	245	37·50	243			

[1]Phil. Mag., 5th ser., vol. 31, 1891, p. 10. I have always found it preferable to use oily instead of aqueous liquids, by which fine parts of steel are liable to rust.

Digitized by Google

TABLE 32.—*Cyclic comparison of the Bourdon gauge (steel tube) with the Amagat manometer. Fraunhofer micrometer.*

Bourdon.	Amagat.	Amagat.	Bourdon.	Amagat.	Amagat.
Cm./40	*Cm.*	*Atm.*	*Cm./40*	*Cm.*	*Atm.*
19·09	·00	0	18·92	·10	1
16·04	35·30	228	15·83	37·40	242
16·12	35·10	227	15·87	36·90	239
11·93	80·80	523	11·91	80·80	523
12·19	80·10	518	12·20	79·30	513
8·40	119·30	772	8·86	112·80	730
8·58	118·30	765	9·18	111·30	720
5·23	149·80	969	5·25	149·80	969
5·66	147·80	956	5·70	147·80	956
6·02	141·30	914	6·16	144·50	935
6·12	141·30	914	6·33	139·30	901
7·94	116·30	753	8·20	116·80	756
8·36	116·30	753	8·39	114·30	739
11·20	82·70	535	11·08	83·30	539
11·28	82·60	534	11·08	83·30	539
15·18	38·80	251	14·80	41·80	270
15·18	39·20	254	14·80	42·40	274
18·97	·00	0	19·06	·00	0

DISCUSSION OF RESULTS.

62. *Multiplying mechanism.*—Constructing Table 31 graphically, it appears that within the errors of reading the observations of the first two series lie on a straight line. In series 1 the "on" and "off" measurements possibly suggest a cycle whose maximum divergence is not above 5 atmospheres. The factor of the Bourdon gauge $\left(\frac{\text{Bourdon}}{\text{Amagat}}\right)$ taken from these data is ·998 "on," and ·987 "off." In series 2 this factor has changed to ·984 "on," and ·992 "off." There is no cyclic march. It follows from both series, barring observational errors, that a cyclic march within an interval of 500 atmospheres does not occur.

The third series "on" shows a change of rate above 700 atmospheres; thus the locus is composed of two straight lines. The return march is now distinctly cyclic, and at 500 shows a breadth of almost 50 atmospheres. The zero is regained within 10 atmospheres. The mean factor is ·991 below, and 1·008 above 700 atmospheres in the "on" march. The mean factor of the "off" march is of no interest. In the fourth series, finally, the remarks made relative to series 3 are substantiated throughout. The factor below 700 atmospheres is ·982, and above 700 is 1·072. There is some error in this last result, probably due to unwarrantably vigorous tapping of the gauge. The width of the cycle at 500, about 50 atmospheres.

Hence, the inferences drawn in the earlier paper from a direct comparison of the Bourdon and Tait gauges[1] are valid throughout. It is gratifying to note that even the standard atmosphere formerly used is correct to ·8 per cent. The present results, however, go further in showing that the cyclic march in question is in the Bourdon gauge, whereas the indications of the steel Tait gauge are probably very near the truth. Since I reversed the action of the Bourdon mechanism at different test

[1] Phil. Mag., 5th ser., vol. 30, 1890, pp. 343 et seq.; ibid., § 18; the breadth of cycles here was about 40 atmospheres.

Digitized by Google

readings it can not be supposed that these cycles are in the multiplying gear. Nevertheless this test is essential, and the results obtained are given in the next paragraph.

63. *Fraunhofer micrometer.*—Care was taken to fix the axis of the screw parallel to the line of motion of the free end of the Bourdon gauge, which makes an angle of nearly 45° with the tangent at the end of the tube. Table 32 shows the total motion to have been about 4^{cm} per 1,000 atmospheres, where it is to be noted, however, that the solid tapering conoidal plug at the end of the flat tube was about 10^{cm} long. Of the two series given in Table 32, the "on" march of the first shows some convexity upward. The factor is $\cdot 362^{cm}$ per 1,000 atmospheres. The data of the "off" march show distinct convexity downward. Hence the two curves form a cycle whose breadth at 500 atmospheres is about 40 atmospheres, a result agreeing substantially with § 62. The data of the second series, which show rather better agreement among themselves, corroborate the results of the first series throughout. The mean factor in the "on" march is $\cdot 361^{cm}$ per 1,000 atmospheres—nearly identical with the above.

The bow-shaped cycles, therefore, obtained in the present and earlier paper[1] represent a case of actual hysteresis. A certain amount of strain is stored up in the Bourdon tube during the interval of compression, which, during removal of pressure, is always relieved more slowly than pressure decreases. The phenomenon is thus static in character, and I venture to regard it as depending on the occurrence of volume lag in those parts of the tube which are directly influenced by pressure. In other words, the molecules of metal near the inside of the Bourdon tube pass from the original to a second molecular state in proportion as a certain pressure P is approached and exceeded, whereas these molecules pass from the second molecular state back to the first again in proportion as pressure falls below a certain other datum p, where $P>p$. Now, inasmuch as Table 31 shows that within 500 atmospheres there is no appreciable hysteresis, while both Tables 31 and 32 show marked cyclic changes between 0 and 1,000 atmospheres, it follows from the data in question that P must lie somewhere between 500 and 1,000 atmospheres, whereas p may lie below 300 atmospheres. Here, therefore, is a phenomenon very similar to the effect of pressure on an undercooled liquid.

Two other possible explanations of the cyclic changes may be noted. In the first place, it is conceivable that the Bourdon tube is hotter during the "off" march than during the "on" march. To test this directly it would be necessary to submerge the tube in a water bath, which is scarcely feasible without injuring the mechanism. But I hold such an explanation improbable. If it were true the comparison within 500 atmospheres (Table 1) should show a cyclic magnitude pro-

[1] Phil. Mag., 5th ser., vol. 30, 1890, pp. 344 et seq. See Pl. x. Cf. chap. I, § 16, above.

Digitized by Google

portional to the cycle corresponding to the interval 1,000 atmospheres, which it does not. Again, the cycles should quite vanish on long waiting (five minutes were allowed per observation in my earlier work), which they do not.

The other explanation, which seems to me equally improbable, is this: There may be two figures of equilibrium of the Bourdon tube, one corresponding to low pressure the other to high pressure, and the figure of labile equilibrium through which the tube passes from the first to the second may be maintained over a relatively large interval of pressure.

In general, therefore, it follows that if the Bourdon gauge is to be used for high pressures, it is necessary to take cognizance of discrepancies inherent in the chemical physics of the metal, in addition to the mathematical difficulties discussed by Lord Rayleigh, Profs. Greenhill and Worthington.

64. *The Tait gauge.*—In Table 33 I give two series of cyclic comparisons of the Tait gauge with the Amagat manometer. The plan of work was similar to that described in section 61. Readings were made in triplets—two at the Amagat manometer, including one at the Tait gauge. An interval of two minutes was allowed for cooling. The Tait gauge used is the same to which my earlier observations apply.[1] The interval of comparison is 1,500 atmospheres. At the end of Table 33 a short résumé of the factors (cm. atm.) corresponding to consecutive pressure intervals is given.

TABLE 33.—*Cyclic comparison of Tait gauge (steel tube) with the Amagat manometer.*

Tait.	Amagat.	Amagat.	Tait.	Amagat.	Amagat.
Cm.	*Cm.*	*Atm.*	*Cm.*	*Cm.*	*Atm.*
12·65	·20	1	12·90	·00	0
21·05	38·30	248	21·30	38·00	246
20·73	37·00	239	20·95	36·40	236
29·35	75·30	487	30·17	76·90	496
28·75	72·30	468	29·25	73·10	484
40·80	124·30	804	38·82	114·80	743
39·72	118·70	768	38·09	111·90	724
51·05	168·00	1,087	50·14	163·50	1057
50·16	163·70	1,059	49·10	159·60	1,033
59·20	201·70	1,305	60·19	206·50	1,335
57·80	195·60	1,266	58·58	200·00	1,294
64·90	225·60	1,460	65·42	228·90	1,481
63·98	221·30	1,432	64·05	222·10	1,437
63·30	218·60	1,414	62·50	216·00	1,398
62·50	215·40	1,394	62·00	213·90	1,384
57·20	192·70	1,247	58·50	199·20	1,289
56·65	190·10	1,230	58·15	197·30	1,277
49·05	157·70	1,020	49·49	160·50	1,038
45·50	155·20	1,004	49·28	159·50	1,022
41·00	123·00	796	40·45	121·30	785
40·72	121 40	786	40·23	120·50	780
31·92	83·30	539	29·86	75·60	489
31·57	82·00	530	29·50	74·20	480
22·44	41·90	271	20·01	32·40	210
22·49	42·10	272	20·06	32·30	209
13·05	·10	1	12·85	—·10	—1
12·85	·10	1	12·93	—·10	—1

[1] Phil. Mag., 5th ser., vol. 30, 1890, p. 344, § 18, gauge No. 1.

Digitized by Google

Factors of the Tait gauge.

Series.	Pressure interval.	Factor.	Means on and off.	Mean total.
	Atm.	*Cm. atm.*	*Cm./atm.*	
I, on...	200 to 1,100	·03580		
I, on...	500 to 1,300	3649	·03628	
I, on...	800 to 1,500	3684		
I, off...	800 to 1,400	·03595		
I, off...	500 to 1,200	3577	·03576	
I, off...	300 to 1,000	3555		
				·03596
II, on...	200 to 1,000	·03544		
II, on...	500 to 1,300	3602	·03590	
II, on...	700 to 1,500	3625		
II, off...	800 to 1,400	·03604		
II, off..	500 to 1,300	3591	·03591	
II, off...	200 to 1,000	3579		

65. Table 33 substantiates the inferences of section 62 relative to the absence of cycles in the registry of the Tait gauge. In the first series, "on," the data above 300 atmospheres make up a straight line. Between 0 and 300 atmospheres the registration of the Tait gauge is too high, being more in error as the pressure zero is approached, where the discrepancy is 30 atmospheres. In the "off" march all the points lie on a straight line, excepting the zero, which is 10 atmospheres too high on the Tait gauge. Thus the locus consists of two straight lines converging at 1,500 atmospheres, and the cyclic character of the data in section 61 does not appear. In the second series, though preserving the general character of series 1, the "off" march practically returns in the line of the "on" march. Thus again true cyclic changes are absent.

As a whole, therefore, the observations lie on a very flat curve, which above 300 atmospheres passes into a straight line. (See Fig 11.) It is difficult to conjecture the cause of this curious low-pressure discrepancy in consequence of the great number of errors which may possibly be encountered, though it may be remarked that the rise of temperature of a liquid per 100 atmospheres of compression may decrease with increasing pressure, since at low pressures compressibility is relatively large. Table 33 shows, finally, that the mean factor derived from all the series is .03596 cm./atm. This is to be increased about 4 per cent, to correct for the temperature of the mercury column of the manometer. Hence the factor is .0361 cm./atm. In my former paper the results[1] were .0360 to .0369 cm./atm., showing that my standard atmosphere must have been less than 2 per cent in error. It is altogether probable that this difference of factor (2 per cent) is the result of the excessive use and abuse to which the gauge was put during the intervening nine months. Regarding the observations as a whole I believe the residual discrepancies to be due rather to unavoidable fluctuations of the temperature of the water jacket than to thermal effects of compression, or viscosity of metal. For this reason I doubt whether any permanent expansion of the metal within 1,500 atmospheres has been registered.

[1] Phil. Mag. 5th ser., vol. 30, Table IV, p. 345. This table contains cm./atm. instead of cm.$\times 10^6$/atm.

Digitized by Google

SUMMARY.

66.—In the attempt to carry these comparisons above 2,000 atmospheres, I ruptured the stout tube which connected the compressor with the manometer. The above work, however, shows conclusively that the Tait gauge may be perfected so as to be available for precise measurement. It may be permissible to indicate the way in which I am endeavoring to do this here; since many of the experimental contrivances involved have already been tested. The tables have shown that the most annoying difficulty is encountered in maintaining the temperature of the water jacket sufficiently constant. To this end the whole gauge is to be constructed of metal with close-fitting jackets. Furthermore, choice is to be made of as thin walled a steel measuring tube as possible, in order that the volume increase due to pressure, may be large relatively to the simultaneous effects of fluctuations of temperature. There is reason to believe that this can be accomplished by connecting the Tait gauge with the compressor by an interposed "piston libre." In the annexed diagram, Fig. 12, let *B* be the cylindrical piston, consisting of a single piece, of which one end is larger in diameter than the other. Let this piston fit the hollow cylinder *C C C* accurately, so as to be capable of motion to and fro and of rotation, with the minimum of friction. Let the tube *D* be in connection with the compressor, the tube *E* in connection with the Tait gauge, and the whole apparatus be filled with oil. Then it is clear that

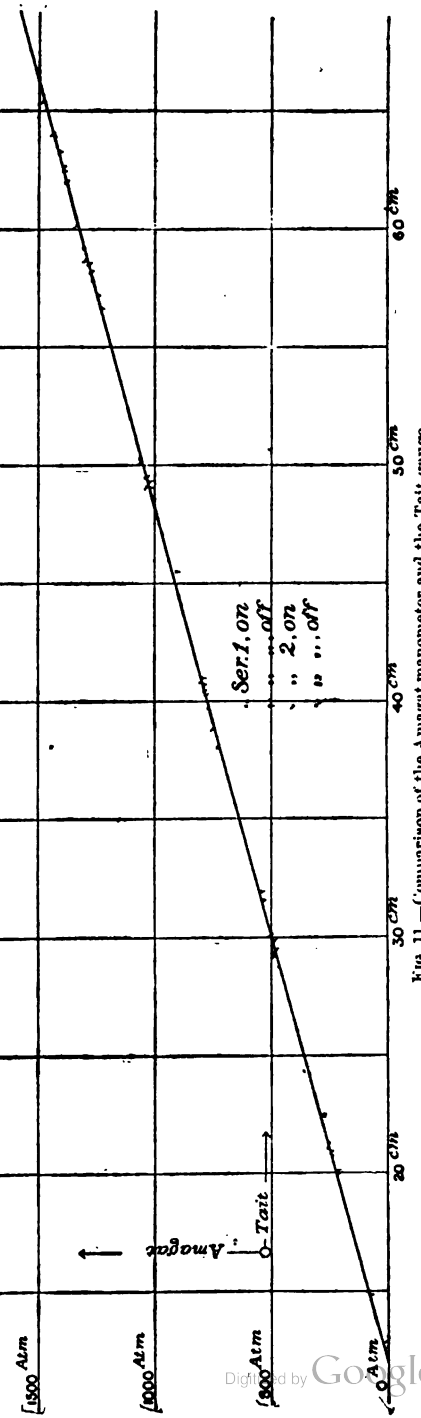


FIG. 11.—Comparison of the Amagat manometer and the Tait gauge.

Digitized by Google

the exceptionally high pressure, acting only on the shoulder of the piston, can be counterbalanced by a relatively low pressure at *E*. Leaving the essential details of construction out of consideration, a Tait gauge reading to only 1000 atmospheres may thus be made to indicate pressure 2, 3, or more times as large as this at *D*, by selecting suitable dimensions of piston and socket. Hence even very high pressures can be measured by aid of a thin-walled steel tube, the pressure expansions of which are so large that the accompanying thermal fluctuations of the environment dwindle to very small importance. I am far from underestimating the importance of Amagat's manometer as a standard

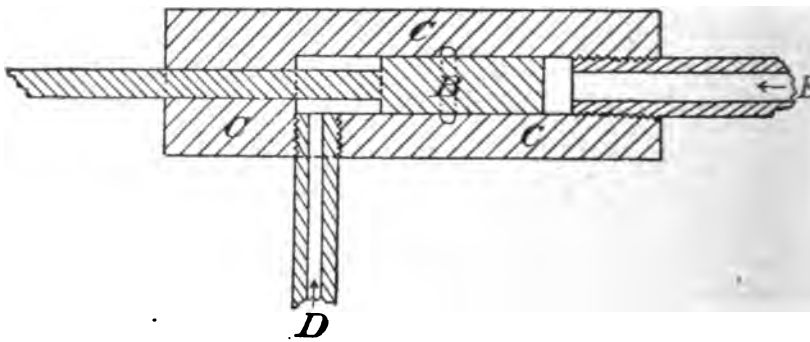


FIG. 12.—"Piston libre," for high pressure.

instrument leading at once to absolute results; but it is certainly inconvenient to be obliged to make readings on a column of mercury which may be 5 meters high, even when a stirring arrangement such as that described in § 60 is provided. I doubt, moreover, whether it would conduce to convenience, and certainty if the readings were made by some easily devised electrical method. On the other hand, in case of the Tait gauge, the pressures are read off on a horizontal tube about 1 meter in length and as far as 2000 atmospheres without "pistons libres," and therefore quite without diminution of pressure in consequence of unavoidable leakage. Regarding gauges quite free from leakage, I hope soon to be able to communicate results on the electrical behavior of pure mercury under pressure.

Digitized by Google

CHAPTER IV.

THE CONTINUITY OF SOLID AND LIQUID.[1]

INTRODUCTORY.

67. *Scope of the work.*—In my earlier papers[2] I entered somewhat minutely into the volume thermodynamics of fluid matter. The behavior of matter passing from liquid to solid and back again was only incidentally considered.[3] This, however, is the very feature which gives character, or at least a more easily interpretable character, to the whole of the volume phenomena of the substance, and I have therefore reserved it for special research.

The problem may be looked upon from another point of view. Let it be required to find the relation of melting point and pressure. I have long since shown[4] that in a comprehensive attack of this question the crude optical or other methods hitherto used as criteria of fusion (criteria which have no inherent relation to the phenomenon to be observed) must be discarded. In their stead the volume changes which nearly always accompany change of physical state in a definite or simple substance are to be employed.

The present experiments were made with naphthalene only. They are by no means even near the degree of precision of which the applied plan of research admits. My chief object here has been to carry the method quite through to an issue preliminarily and to test it at every point. The data are sufficient, however, to show that the process adopted, though I approached it with much misgiving, can be brought under control throughout, and that the attainable accuracy is only limited by the patience, discernment, and skill of the observer. I was in some degree surprised therefore to find that my method led to new results at the outset.

The literature of the subject I shall omit here, since the more important experiments have entered the text-books and since I shall have occasion to refer to it elsewhere. I need merely mention Sir William

[1] The geological interpretation of this work is in the hands of Mr. Clarence King, by whom the inquiry was suggested.

[2] Am. Jour. Sci., 3d ser., vol. 38, 1889, p. 407; ibid., vol. 39, 1890, p. 478; ibid., vol. 40, 1890, p. 219; ibid., vol. 41, 1891, p. 110; Phil. Mag., 5th ser., vol. 30, 1890, p. 338.

[3] Am. Jour. Sci., 3d ser., vol. 38, 1889, p. 408; ibid., vol. 39, 1890, pp. 490, 491, 494. Most of my earlier work on this subject has thus far remained unpublished.

[4] Am. Jour. Sci., loc. cit. More pointedly with an indication of methods in Phil. Mag., 5th ser., vol. 31, 1891, p. 14.

Digitized by Google

Thomson (1850), Bunsen (1850), Hopkins (1854), Mousson (1858), Poynting (1881), Peddie (1884), Amagat (1887), Battelli (1887), and some others (cf. § 95, 96).

68. *Other methods tested.*—In applying this principle I first made direct volume observations on substances inclosed in capillary tubes of glass. In the case of naphthalene and many others I thus obtained satisfactory results[1]. Such work is, however, limited to relatively low pressures (600 or 800 atmospheres); it does not admit of sufficient correction for the volume changes of the glass, and for the small quantity of substance examined and the relatively frequent occurrence of nuclear condensation, volume lags are often obscured. Hence the definition which, after making these experiments, I was inclined to adopt, viz, that a pressure which when acting isothermally for an infinite time will just solidify the liquid and just liquify the solid, stands to the given temperature in the relation of melting point and pressure, is not in accordance with the facts.

In a second method[2] I endeavored to measure the characteristic difference of specific volume by passing current through the thin, hot walls of the tube which contained both the substance and the mercury thread or index. The whole apparatus is in this case surrounded by the oil of the piezometer in which the tube is inserted, and the changes of resistance of the arrangement indicate the motion of the index and hence the degree of compression produced. Here, however, a new and unexpected annoyance was encountered, inasmuch as both the medium of oil and the glass possess seriously large pressure coefficients.[3] Moreover it is only with great difficulty that perfect insulation can be maintained in an apparatus of which water jackets make up an essential part. I therefore abandoned this project.

In a third method similar to the preceding I expressed the motion of the mercury thread or index in terms of the resistance of a very fine platinum wire passing through the axis of the tube. The successive intercepts thus indicated the changes of volume to be observed. This method gave good indications of the pressure positions of the melting points of the sample. It failed, however, to give serviceable values for the fluid volume changes. This is due to the fact that contacts in such a case are essentially loose. Again thermo-currents can only with great difficulty, if at all, be allowed for, seeing that the successive isothermal temperatures are to vary over a large range.

Finally all of the methods above described must necessarily fail after the substance has become solid, for in this case the thread or index is broken and forced into the interstices of the solidified material. Thus it is manifestly impossible to retain a uniform meniscus after solidification has once set in, and it is therefore impracticable both to arrive

[1] Cf. American Journal of Science, vol. 38, 1889, p. 406.
[2] Phil. Mag., 5th ser., vol. 31, 1891, p. 14.
[3] Ibid., pp. 18 to 24, et seq.

Digitized by Google

at the behavior of the solid, as well as to rigorously coördinate successive series of experiments.

69. *Advantages of the present method.*—Hence I endeavored to modify Kopp's[1] specific volume flask in a way to make it available under any temperature or pressure. Here the readings are independent of the unbroken character of the meniscus immediately in contact with the solidifying substance, whereas on the other hand, as I shall presently show, the expansion measurements can be made electrically[2] with almost any desirable degree of accuracy. Furthermore, by charging the flask with properly apportioned quantities of substance and of mercury, the error due to the compressibility of the glass may be eliminated in any degree whatever, and an apparatus obtained which is practically rigid in relation to pressure. The data show that from each single series of experiments I thus obtain the isothermals and isopiestics, and therefore also the isometrics, both for the liquid and for the solid; furthermore the relation of melting point and of solidifying point to pressure, and finally the changes of the isothermal specific volumes of solid and liquid at the melting points, with pressure. From these results the character of the fusion and the probable position of critical (§92) and transitional (§94) points can already be pretty well predicted. It is then only necessary to examine a great number of substances, of substances existing under widely different conditions of thermal state, in order to broaden the evidence and possibly to reach results of a uniform bearing on matter in general. This I indicated elsewhere.[3]

APPARATUS.

70. *Temperature.*—Inasmuch as pressure varies at a mean rate of, say, 30 atmospheres per degree, so that temperature is as it were the coarse adjustment and pressure the fine adjustment for the conditions of melting point, it is clear that the method of experiment should be such that temperature may be kept rigorously constant while pressure is made to vary over the necessary interval. To obtain constant temperatures I constructed a set of vapor baths of well-brazed, thin sheet iron heavily jacketed with asbestos. Cf. Pl. III, *pppp*. These were cylindrical in form, 10^{cm} in diameter and 20^{cm} high. Axial tubulures, the upper of which, *ss*, projected outward, the lower, *oooo*, both inward and outward, allowed the vertical tubular piezometer to pass axially through the vapor baths, and suitable stuffing boxes obviated all possibility of leakage. Again the upward projection of the lower tubulure (both of them fit the piezometer snugly) formed an annular trough with the walls and bottom of the vapor bath, in which a sufficient quantity of the ebullition liquid could be placed and boiled by aid of a flat spiral burner

[1] Kopp, Ann. Chem. u. Pharm., vol. 93, 1885, p. 129.

[2] The absolute expansion and compressibility of mercury being now known § 73.

[3] "Instead of tracing the isothermals of a single substance throughout enormous ranges of pressure, similarly comparable results may possibly be obtained by examining different substances conceived to exist in widely different thermal states." (Am. Journ., loc. cit., p. 510.)

Digitized by Google

placed below. The top of the vapor bath was provided with two other lateral tubulures, one of which served for the permanent attachment of a vertical condenser and the other for the introduction of a suitable thermometer or thermocouple. Here also the quantity of ebullition liquid present could at any time be tested and its amount increased or diminished, or its quality directly purified by fractional distillation (an operation always necessary when amyl alcohol is used). With a good condenser the boiling may be kept up indefinitely, since the condensed vapors fall back into the trough below. For temperatures below 100° it is expedient to avali oneself of the high latent heat of water and to boil this liquid under diminished pressure. Temporarily attaching Richards's jet pump to the end of the condenser, pressure may be so regulated that any boiling point between 50° and 100° is maintained indefinitely. For higher temperatures amyl alcohol, turpentine, naphthalene, benzoic acid, diphenylamine, phenanthren, sulphur, etc., subserve the same purposes, though less thoroughly. Low latent heats[1] in most of these substances make it difficult to guarantee perfect thermal constancy throughout a length of say 10^{cm}. (Cf. §72, where a view of the apparatus is given.)

Temperature was measured by aid of a Baudin thermometer of known errors and also computed from the vapor tension of steam under known conditions. Thermolectric measurements are similarly applicable.

71. *Pressure.*—To obtain pressures as high as 2,000 atmospheres I used my screw compressor described elsewhere.[2] I made use, however, of a vertical piezometer, identical with the horizontal piezometer there described, except in so far as it could be removed from the barrel as a whole. As before, moreover, piezometer and barrel are insulated. When in adjustment the piezometer was surrounded by the following parts enumerated from bottom to top (see Pl. III): An insulated conical protector or guard preventing spilled water, etc., from reaching the insulation, the lower cold-water jacket, the flat burner, the vapor bath, and finally the upper cold-water jacket. For temperatures below 200° the latter may be dispensed with.

Internally the piezometer was filled with thick petroleum oil, as stated elsewhere.[3]

For pressure measurement I am now able to avail myself of a superb Amagat manomètre à pistons libres, which can be immediately attached to my compressor with advantage.

72. *The volume tube.*—A careful description of this apparatus, together with the operations necessary in standardizing it, is essential here. In one case these preliminary operations have led to a result of an interest apart from the present special purposes.

The tube is shown in the annexed diagram, Fig. 13, while Pl. III

[1] It is my object in further experiments to boil water under pressure.
[2] Proc. Am. Acad., vol. 25, 1890, p. 93, Chapter I, above.
[3] Phil. Mag., 5th ser., vol. 31, 1891, p. 10, chapter III, above.

Digitized by Google

shows the tube in place in the tubular piezometer. It consists of an external cylindrical envelope, *A B*, of glass, closed below, open above, about 26^{cm} long and .4^{cm} or .5^{cm} in diameter. Throughout the greater part of its length, the tube *A B* is divided into two coaxial cylindric compartments, by a central glass partition tube, *Ck C*, open at both ends and fused to the tube *A B* along the ring *C C* about 7^{cm} below the open top *A*. This central tube *Ck C* is about 17^{cm} long and .13^{cm} internal diameter, and drawn as thinwalled and as even in caliber as possible, so that the greater part of its lower length may be available for measurement. It extends nearly to the bottom of *A B*.

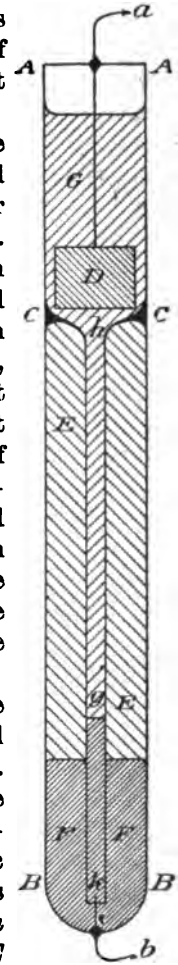


FIG. 13.—Diagram of the volume tube.

The substance to be examined is introduced into the annular space *E E*, care being taken that when fused under the highest temperature to be applied its lower boundary may be 4^{cm} or more above the end *k* of *Ck C*. My fused samples were about 13^{cm} long. Immediately in contact with the substance *E E* and extending upward into the central tube *Ck C* is the plug of mercury *F F* with its free meniscus at *g*. When *E E* is solid *g* must be, say, 2^{cm} above the end *k* of *Ck C*, and when *E E* is liquid at the highest temperature to be applied *g* must still be at about an equal distance below *C C*. The remainder of the tube above *g* is quite filled with a concentrated solution of zinc sulphate *Ghg*, into which an amalgamated zinc terminal, *D*, has been submerged and fixed in position by aid of platinum wire *a*, fused to the sides of the tube *A B*, as shown. The other terminal, *b*, is fused into the bottom of the tube *A* and in metallic connection with the mercury, *F F*, therein contained.

The tube thus adjusted is completely submerged in the oil contained within the tubular piezometer, Pl. III, and pressure is uniformly transmitted to it through the oil. The terminal *a* is put into metallic connection with the insulated piezometer; the terminal *b*, completely insulated therefrom by a coating of glass tube, is in metallic connection with the barrel; the tube *A B* itself is thus held in position by tensely stretching the fixed wires *a* and *b* and so adjusting their lengths that the parts *E E* and *hg*, with reference to which the measurements are made, may lie wholly within the *vapor* reservoir of the cylindrical vapor bath surrounding the piezometer. The method of fastening the ends *a* and *b* is a somewhat delicate operation, which, however, I will not further describe. So adjusted the tube is in position (vertical as shown in Pl. III) for any number of experiments and it is only necessary to attach the vertical piezometer to the barrel by aid of a tinned axially perforated screw.

Digitized by Google

An inspection of the diagram shows at once that if a current enter the outside of the barrel it will pass through *b*, *k*, *g*, *h*, *D*, and *a* into the outside of the piezometer and thence back to the battery. The only relatively significant resistance encountered in this course need be that between *g* and *h* of the thread of zinc-sulphate solution; but this resistance, cæteris paribus, varies directly with the length of *gh*, and therefore proportionally to the volume contraction of the substance *E E*. Hence the volume variations of the substance to be studied are directly and rigorously measurable in terms of the resistance of the circuit. If Kohlrausch's method[1] of intermittent currents, bridge, and telephone be used for the resistance measurement of the electrolyte, solidification or fusion breaks upon the ear with a loud roar, whereas the ordinary volume changes (solid or liquid) are indicated by mere intensification of sound, sufficiently pronounced to subserve the purposes of measurement.

It is seen that any breakage of the surface of separation between *E E* and *F F* is entirely without influence on this result, and that, even in the case of the solidification of *E E*, when mercury is forced into the interstices left after contraction, the compressibility of *E E* will still be measurable.

The charging of the tube, free from air, is an operation which I have not thus far accomplished satisfactorily. If a volatile substance like naphthalene be filled into *E E* and fused in vacuo, the vapor subsequently condensing in *gh* will soil the tube and interfere with measurement. From the solid *E E* I doubt whether air can be quite eliminated in vacuo. Hence in the present work the substance was not air-free, a condition of things to which I gave less attention because I do not believe the melting points can be appreciably influenced by dissolved air, nor that other of the measurements made are seriously distorted by this error. In the future, however, I will endeavor to meet this difficulty by fusing the end *A A* of the tube *A B* inverted to the top of a barometer tube, in addition to a lateral tubulure leading to a Sprengel pump. If now, after exhaustion, the lower meniscus of the barometric column is adjustable, so that the column as a whole may be raised quite into the tube *A B* or withdrawn from it at pleasure, it is probable that a thorough vacuum filling may be effected. Rubber connections, which corrode and blacken warm mercury, must be scrupulously avoided.

If the whole apparatus be charged with pure mercury in the place of the substance *E E*, the expansion and compression constants of the tube may be found as stated in the next paragraph.

Again, even if the measuring thread in *gh* should break into parts alternating with threads of zinc sulphate (a possibility when the thread is worked up and down many hundred times, particularly in view of the suddenness of solidification), the constants of reduction are not thereby necessarily vitiated, always supposing that the number of

[1] Kohlrausch: Wied. Ann., vol. ii, 1880, p. 653; Long: ibid., 1880, p. 57.

Digitized by Google

q

Digitized by Google

Digitized by Google

such breaks is not greater than one or two. Special care, however, must be taken to avoid contact of the mercury thread and the upper zinc terminal. Such an occurrence would either add to or deduct from the length of the thread and produce shifting in the coordination of the volume measurements. The formation of zinc amalgam after the long continued passage of intermittent currents or the possible electric solution of mercury is again to be kept in view, as is also the probable change of compressibility of amalgamated mercury. On all these points I shall make special tests. Solution of mercury, however, can not become of serious consequence, since the column *gh* is continually washed by the zinc terminal *D*.

To give a succinct view of the method of work I will insert Pl. III, which shows the volume tube *rr* in place in the tubular piezometer *uuuu*. The upper terminal *rw* is in contact with the screw plug *v*, where *w* is fastened. The lower terminal *rxx* is completely insulated from *uu* by a glass tube (not shown) and metallically fastened to the perforated connecting screw *a*, by which the piezometer is attached to the barrel (not shown) of the compressor. The insulation of *uu* from *bb* and *a* has been described in section 12 above, *cc* being of steel, *dd* and *kk* of hard rubber, the whole being made tight by a medium of marine glue and secured by the steel gland *ee*. The hard-rubber disc *zz*, prevents the external terminal *ggg* of the piezometer from coming in contact with the metallic parts below and the barrel, while a conical screen or umbrella of sheet iron, *ffff*, additionally protects the lower insulation from water or liquid drippings from above. Note that *ff* is insulated from *nn* by a rubber cork, *hh*. The vapor bath, *pppp*, placed as shown, is heated by the plate burner *rr*, adjustable at pleasure, and an asbestos jacket, *iu*, keeps superfluous heat away from the tube *uu*. The axial tube *oooo* of the vapor bath is sealed below by a piece of rubber hose, *mm*, or by a metallic stuffing box, care having been taken to make *oooo* fit the piezometer tube closely and thus take as little liquid out of the annular ebullition trough already described as possible. The condenser *qq* is connected above with an air pump (not shown). Finally water jackets *tt* and *ll*, through which a current continually circulates, confine the heat to the central parts of the piezometer tube *uuuu*.

METHOD OF MEASUREMENT.

73. *Constants of the tube.*—In order that the present measurements may be carried out absolutely it is necessary to know—

(1) The volume of the charge at a fiducial temperature and pressure.

(2) The volume of the plug of mercury under the same conditions.

(3) The volume of the central or measuring tube *kh* per centimeter of length.

(4) The resistance of the thread of zinc sulphate solution per centimeter of length under all the stated conditions of temperature and pressure. From 3 and 4 there follows at once—

Digitized by Google

(5) The resistance of the thread of zinc sulphate per unit of volume under stated conditions of temperature and pressure. Thus it is necessary to investigate preliminarily—

(6) The isopiestic relation of resistance and temperature of the given concentrated solution of zinc sulphate and

(7) The isothermal relation of resistance and pressure of the same solution. In other words, it is necessary to know what may be called the isoelectrics relative to temperature and pressure of the measuring electrolyte. Furthermore, it is necessary to find or to know—

(8) The compressibility of glass in its relations to pressure and temperature, and

(9) The compressibility of mercury under the same conditions, and, finally,

(10) The thermal expansion of glass and

(11) The thermal expansion of mercury under the given conditions of pressure.

The measurements 8 to 11 I did not make directly; they are of smaller importance, seeing that the substances on which I operate are all characterized by relatively large volume change. Such measurements are, however, easily feasible, since both the expansion constants and the compression constants of pure mercury (thanks to the recent labors of Amagat, Tait, and Guillaume) are now thoroughly known, and it is also known that the thermal changes of the elastics of glass are of no relative consequence (Amagat), even as far as 200°. I assumed the compressibility of my glass[1] to be ·0000022, that of mercury[2] being ·0000039; moreover, the coefficient of expansion of glass[3] to be ·000025, that of mercury[4] being ·000182 between 60° and 130°.

74. *Volume of the charge.*—Clearly the fiducial conditions to which volume is to be referred are given by the (normal) melting point under atmospheric pressure. By weighing the tube before and after charging I found the mass of naphthalene inclosed to have been ·763 gramme. In a special and duplicate set of pycnometer experiments I furthermore found the density of naphthalene, fused at 82°, to have been ·724. Hence the volume of the charge at 82° is ·552^{cm3}, which I accepted as identical with the volume at the melting point (80°).

75. *Corrections for expansion and compressibility of envelopes.*—The plug of mercury weighed 7·74 grammes. Its volume is therefore ·571^{cm3} at 20°, and its mean volume between 60° and 130°, being between ·575 and ·582, is sufficiently near ·58^{cm3}.

Thus the volume of the glass tube containing both the charge of naphthalene and mercury was 1·13^{cm3}. Its expansion per degree centigrade ·000028^{cm3}, while the expansion of the actually inclosed mercury per degree centigrade was ·000105^{cm3}, where the apparent expansion

[1] E. H. Amagat: Ann. ch. et phys., 1891, p. 125.
[2] Ibid., p. 137.
[3] Landolt u. Boernstein's Tables, 1883, p. 69.
[4] Ibid., p. 37.

Digitized by Google

·000077^{cm3} per degree. Therefore if, in place of the fiducial volume ·552^{cm3} found in §74, the following volumes be substituted, viz,

60°	·5565^{cm3}	100°	·5535^{cm3}
80°	·5550	120°	·5519
90°	·5542	130°	·5311

the tube may be treated as free from thermal expansion. Here at 80° .5550 appears, instead of .5524, to correct for the fiducial volume of the stem *k h* (Fig. 13), as will presently be explained. (§ 83.)

Again, the compression of the 1·13^{cm3} of glass and ·58^{cm3} of mercury will be

100 atm.:	glass, ·00025 ^{cm3};	mercury, ·00023 ^{cm3};	difference, ·00002^{cm3}
500	124	113	11
1000	249	226	23
1500	373	339	34
2000	497	452	45

Thus these corrections, which would individually be appreciable (affecting the increments say 3 per cent), are differentially negligible (0.3 per cent), where they fall below the electrical pressure coefficient of the zinc sulphate solution. (§ 80.) This has already been intimated above (§ 69), and is one of the interesting advantages of the volume tube Fig. 13.

76. *Resistance measurement.*—In making the measurements of resistance of thread it is convenient to use Kohlrausch's interrupter, bridge, and telephone. To facilitate audition I joined the cup of the telephone to a graphophone tube and listened with both ears. The resistances, however, are rather higher than contemplated in Kohlrausch's method, when an ordinary Bell telephone is used. Hence the measurements, particularly near and in the solid state, are far below the limit of attainable accuracy. I shall in future measurements wind telephones specially adapted for my purposes, and endeavor to use both ends of the magnet to actuate diaphragms connected respectively with each ear by an independent tube.

When zinc sulphate is inclosed between terminals of amalgamated zinc a galvanometer is available. In this way I made most of the calibration measurements. Supposing the mercury index to be slightly deadened in its electro-negative qualities by zinc, it may also be used in case of the tube.

77. *Calibration.*—In view of the fact that the central tube *h k* (Fig. 13) is insufficiently uniform in caliber, it is necessary to express volume as a function of length. This I did by weighing threads of mercury whose length in successive parts of the tube had to be measured, obtaining the results of the first two columns of Table 34. The fiducial zero is here arbitrarily placed 2^{cm} below the ring *C C* (Fig. 13), the caliber above this being too variable.

It is next necessary to express the resistance of a filament of the concentrated solution of zinc sulphate as a function of length referred to the same fiducial zero at some convenient (atmospheric) temperature. To do this I drew a zinc wire to a diameter slightly less than the caliber

Digitized by Google

of the tube to be calibrated. Opening the bottom of the tube *A B* (Fig. 13) and closing the top, so as to hold the terminal *D* firmly in position, I inverted the tube and quite filled it with the solution. The tube was then placed in a water bath with the terminal *a* insulated, and the terminal *b* replaced by the zinc wire referred to, and so adjusted that I could slide it up and down the central tube and fix it in any position. Measuring the distance between the ring *C C* (in this case, the neck was quite filled by the fitting terminal) and the free end of the wire with Grunow's cathetometer, and measuring at the same time the resistance corresponding to this length by means of Kohlrausch's Wheatstone bridge (§ 76), I obtained the data necessary for constructing resistance as a function of length for the temperature of the bath. In this way the second and third columns of Table 34 were investigated.

Combining the results of these four columns by graphic interpolation, I obtained the data of the fifth and sixth columns, in which volume is expressed in terms of resistance at 17·8° with regard to the fiducial mark in question.

TABLE 34.—*Volumes per unit of length. Calibration resistance per unit of length, θ=17·8°. Volume per unit of resistance, θ=17·8°.*

Length.	Volume.	Length.	Resistance.	Resistance. $\theta=17\cdot8°$.	Volume. $\theta=17\cdot8°$.
Cm.	*Cm³.*	*Cm.*	*Ohms.*	*Ohms.*	*Cm³.*
3·00	·0491	— ·06	2720	2800	·0000
11·15	·1609	2·13	5780	5530	·0350
		4·75	10190	8850	·0640
		7·96	16200	12530	·0920
4·45	·0715	12·06	24340	16270	·1190
9·79	·1430			20250	·1450
15·42	·2145			24250	·1705
		1·38	4630	28500	·1960
		3·43	7920		
3·30	·0538	6·18	12790		
7·20	·1076	9·00	18220		
11·40	·1614	11·49	23140		
15·60	·2152				
		·11	2930		
2·75	·0470	2·78	7050		
6·10	·0940	Air bubble error.			
9·65	·1410				
13·40	·1880				

78. *Electrolytic resistance and temperature.*—It is next necessary to express the variation of the resistance of the concentrated zinc sulphate solution with temperature. This is a general problem apart from the apparatus used. Nevertheless I made two sets of measurements, in the first of which I measured the resistance of the thread *kh*, Fig. 13, between fixed terminals of zinc, when the whole was kept at successive constant temperatures and under pressure sufficient to keep the thread liquid and to thoroughly condense all polarization gases. The first four columns of Table 35 contains these results, all easily intelligible except the last column perhaps, where under R/R_{100} the relative resistance referred to the resistance at 100° C. is inserted. At 100° the pressures were varied to measure the pressure coefficients dis-

Digitized by Google

ussed in the next paragraph. In the second and third parts of the able the above tube was replaced by a plain straight tube. Resistnces are much smaller here, but the column R/R_{100} makes both series omparable.

ABLE 35.—*Temperature coefficients and pressure coefficients of concentrated zinc sulphate solution.*

[First series. Length of thread 10.70cm or 8.7cm from fiducial mark. Diameter of tube .13cm.]

Temperature.	Pressure.	Resistance.	R/R_{100}
°C	*Atm.*	*Ohms.*	
6·3	100	26960	6·059
6·5	100	26960	6·059
66·8	140	6178	1·388
67·3	140	6120	1.376
68·0	140	6050	1·360
67·8	140	6061	1·362
67·8	140	6075	1·365
67·7	140	6075	1·365
100·0	137	4550	1·023
100·0	137	4540	1·020
100·0	479	4470	1·005
100·0	469	4480	1·007
100·0	1019	4370	·982
100·0	996	4380	·985
100·0	1507	4310	·969
100.0	1443	4320	·970
100·0	129	4360	·980
100·0	139	4360	·980
127·6	158	3740	·840
127·8	158	3730	·838
127·8	158	3730	·838
6·5	116	27140	6·100
6·3	116	27000	6·067

[Second series. Plain straight tube, diameter .30cm.

6·7	72	7280	5·824
.....	465	7090	5·672
.....	458	7120	5·700
.....	906	7020	5·616
.....	830	7020	5·616
.....	498	7130	5·704
6·7	492	7050	5·640
.....	139	7190	5·752
.....	147	7160	5·728
99·6	191	1237	.990

Temperature.	Pressure.	Resistance.	R/R_{100}
°C	*Atm.*	*Ohms.*	
.....	186	1242	·994
.....	471	1222	·978
.....	448	1210	·968
.....	1011	1198	·958
.....	981	1203	·962
.....	503	1232	·986
.....	507	1232	·986
.....	126	1262	1.010
126·0	157	1062	·850
126·0	157	1062	·850
127·8	149	1058	·846
127·8	149	1058	·846
160.5	154	980	·787
160·5	154	984	·787
160·5	154	984	·787

[Third series. Same tube.]

16·4	147	4980	3·984
16·4	147	5000	4·000
16·4	147	5020	4·016
6·4	138	7440	5·952
6·4	138	7500	6·000
6·4	138	7500	6·000
61·3	170	1900	1·520
61·3	170	1900	1·520
61·3	170	1913	1·530
85·8	180	1359	1·088
85·8	180	1359	1·088
85·8	180	1364	1·091
99·6	189	1247	1·000
99·6	189	1253	1·002
99·6	189	1253	1·002

If the values R/R_{100} be constructed graphically, as a function of emperature for nearly the same pressures, the results of all the series n Table 35 are found to be in good accord. Moreover the results for he large interval 6° to 160° lie on a locus which in form closely reembles an hyperbola.[1] From this point of view these data are remarkbly interesting, for if this be true then a suitable inversion of the ocus indicates that the electric conductivity of the electrolyte varies inearly with temperature. Such a result would not only possess heoretic interest, but would make measurements of the kind necessary

[1] Experiments recently made by Prof. Iddings and myself with diabase (See Am. Journal Sci., XLIV, pp. 242 and 255) showed a geometrical progression of resistances to correspond to an arithmetical progression of temperature, caet. par. Thus the nature of the above locus is exponential.

Digitized by Google

in the present paper feasible with a high degree of certainty. I must withhold my opinion for the present, however, until I can trace the above locus as far as 300°, and the interpolations of this paper were made empirically.

79. *Volume in terms of resistance.*—With the data of §§ 77 and 78 in hand it is now possible to express the volume of the capillary tube *hk*, Fig. 31, in terms of the resistance of the thread of electrolyte observed at any temperature. This is done in the next table, 36, where the temperatures, θ, are those occurring in the tables of isothermals below.

TABLE 36.—*Relation of volume and resistance at different temperatures.*

Volume.	Resistance.					
	$\theta=63{\cdot}5°$.	$\theta=83°$.	$\theta=90°$.	$\theta=100°$.	$\theta=117°$.	$\theta=130°$.
Cm³.	*Ohms.*	*Ohms.*	*Ohms.*	*Ohms.*	*Ohms.*	*Ohms.*
·0000	1064	818	776	722	636	608
·0350	2101	1615	1532	1427	1255	1200
·0640	3363	2584	2451	2283	2009	1920
·0920	4761	3659	3471	3233	2844	2719
·1190	6183	4751	4507	4198	3693	3531
·1450	7695	5913	5609	5224	4597	4394
·1705	9215	7081	6717	6256	5505	5262
·1960	10830	8322	7895	7353	6470	6185

80. *Pressure coefficient of the electrolyte.*—The divers results of Table 35 for variable pressure and constant temperature are summarized in the small Table 37. Here θ denotes the temperature and k the pressure coefficient, which is negative in sign, showing that pressure decreases the resistance of zinc sulphate. The braces show the manner in which the means were taken, where $k=\delta R/R_0\,\delta p$. R is the symbol of resistance, p of pressure, and R_0 holds at 0° *C*.

TABLE 37.—*Pressure coefficients.*

θ.	Pressure.	$k\times10^6$.	θ.	Pressure.	$k\times10^6$.
7°	119 }	−43	100°	137 }	
	479 }	−35		474 }	−43
	868 }			1007 }	−35
				1475 }	
100°	157 }	−64	Mean $k=-{\cdot}000045$		
	482 }	−49			
	996 }				

This table shows that the pressure coefficient is independent of temperature, and that it decreases somewhat with pressure. The results, however, are not quite consistent, and a graphic construction of the detailed results of Table 35 shows a difference of march in the pressure "on" and the pressure "off" movements. I have yet to learn whether this be due to insufficient fixed terminals or to polarization, as well as to find conditions under which the pressure coefficient may be a minimum. As the results stand the mean value $k=-45/10^6$ is probably within 20 per cent of the truth, and hence in the extreme case of 2,000

Digitized by Google

atmospheres the uncertainty of the pressure coefficient will not affect the volume increments more than 2 per cent.

I may add in passing that the value, investigated in an earlier paper,[1] between 0 and 150 atmospheres was found to be $k = -50/10^6$, agreeing pretty well with Table 37, and I there called attention to the strikingly close proximity of this datum to the corresponding coefficient for mercury, $-30/10$.[2]

The pressure coefficient is of considerable interest, inasmuch as it indicates a certain relation between elasticity and the chemical equilibrium of the solid or liquid operated on.[3] Specially for zinc sulphate compression, which might be regarded as having a concentrative effect on the solution between the terminals, increases the conductivity, whereas the conductivity of a nearly concentrated solution (density >1.29) not under pressure decreases on further concentration.

The admixture of polarization with the pressure coefficient points out the nature of its instability.

RESULTS OF THE MEASUREMENTS.

81. *Arrangement of the tables.*—The following Tables 38 to 43, in which the isothermals of naphthalene are fully given, are constructed on the same plan throughout. The first column contains the time in minutes at which the observation was made, the first date being arbitrary. The (uncorrected) resistance as actually found at the pressure given is shown under R in ohms. The factor kp is the correction for pressure coefficient to be added per unit of R, after which this datum can be graphically expressed as a volume increment, referred as yet to an arbitrary fiducial zero in the way indicated in §§ 79, 80. To deduce from this the corresponding actual volume (last column of the tables) the initial volume values of § 75 are available, relative to which further explanation will be given in § 83. Two data are given for each step of pressure, the second of which, obtained after long waiting, is more nearly isothermal than the first. The difference is not of seriously large magnitude. In most cases, after the volume has become solid, a small amount of additional volume decrement takes place viscously, or in consequence of gradual decrease of temperature immediately after solidification.

The experiments were made on different days and altogether extended over more than a week. This is somewhat too long a time to employ the tube without special readjustment, and some shifting of coördinates may thus have occurred (§§ 91, 92).

Parentheses occur in the following tables, to show that for the data inclosed the measurement was made along a part of the measuring tube *hk* (Fig. 13), whose caliber is not adequately uniform. Without

[1] American Jour., vol. 40, 1890, p. 219. This paper was published some two years after the work was done.

[2] Barus: Phil. Mag. (5th ser.), vol. 31, 1891, p. 24 et seq.

Digitized by Google

knowing the full expansions at the higher temperatures and low pressures, it is, a priori, impossible so to fill the tube that all measurements fall within the calibrated parts and all other calibration conditions are complied with. (§§ 75 et seq.) These approximations, however, refer only to the liquid state, and are therefore of smaller consequence in this paper. (§ 67).)

I may add finally that the melting point of naphthalene in air is 80°, its solidifying point below this; the density of the solid 1·14, and the density of the liquid at 82°, ·724. (§ 74.) Hence naphthalene, if melted in water, sinks or swims, according as its temperature is sufficiently below or above 80°.

82. *Solid isothermal, 63°.*—Since the naphthalene melts at 80°, the isothermal at 63° refers to the solid state. There must clearly be much greater uncertainty in operating on a substance when solid than when liquid. Indeed it is rather remarkable that the solid isothermals are approachable at all. The liquid solidifies to a fissured or honeycombed structure, and it is therefore essential that the mercury should completely fill these interstices before the true compressibility of the substance can be indicated. Similarly the error due to the compressibility of the envelopes now becomes of much greater importance. It is thus solely by comparing these data with similar solid isothermals obtained at much higher temperatures and pressures that their validity may be inferred (§ 72).

TABLE 38.—*Isothermals of (solid) naphthalene at* $\theta = 63{\cdot}5°$, *referred to* ·55^{cm3} *at the normal melting point.*

Time.	Pressure.	R.	$kp \times 10^3$.	Volume.	Time.	Pressure.	R.	$kp \times 10^3$.	Volume.
m.	*Atm.*	*Ohms.*		*cm.*^{3}	*m.*	*Atm.*	*Ohms.*		*cm.*^{3}
16	70	7600	8	·4127	38	859	8240	39	·3965
19	68	7430	3	·4156	40	850	8120	38	·3988
20	289	7760	13	·4085	42	972	8310	44	·3945
23	281	7630	13	·4109	44	966	8310	44	·3945
25	491	8160	22	·4003	46	565	7600	25	·4097
29	481	8010	22	·4027	49	565	7600	25	·4097
34	675	8050	30	·4010	51	100	7270	4	·4183
37	662	7880	30	·4039	67	65	7340	3	·4173

With regard to this series it is curious to note that the recoil of volume (pressure decreasing) is more rapid than the compression. The reverse of this would have been anticipated, supposing that mercury lodged in the interstices after compression. Finally I may state that telephonic resistance measurement, when the values are so high, is not unaccompanied by inappreciable errors. (§ 76.)

83. *Liquid-solid isothermal, 83°.*—Table 39 contains three independent series of measurements, the last of which is fragmentary and the second obtained after the experience of the first, probably the best. The solidifying point is here very gradually approached and the locus shows an initial step of James Thomson's double inflections.

It is from these isothermals that I obtained the fiducial zero of the

Digitized by Google

measuring tube *hk*, Fig. 13. For if R be constructed as a function of pressure it will be found that pressure zero lies at ·0024^{cm3} of volume decrement. Hence the value of § 74 (·5524^{cm3}) increased by this correction is the fiducial volume (·555^{cm3}) here to be used and from this the others are derived as already explained. (§ 75.)

TABLE 39.—*Isothermals of naphthalene at $\theta = 83°$, referred to ·55^{cm3} at the normal melting point.*

Time.	Pressure.	$kp \times 10^3$.	R.	Volume.	Time.	Pressure.	$kp \times 10^3$.	R.	Volume.
m.	*Atm.*		*Ohms.*	*cm³.*	*m.*	*Atm.*		*Ohms.*	*cm³.*
−14	47	2	938	·5490	22	175	8	5493	·4183
−10	45	2	938	·5490	28	179	8	5493	·4183
− 7	164	7	1114	·5404	30	116	5	5061	·4285
− 2	157	7	1100	·5410	36	120	5	5173	·4260
0	259	12	1247	·5340	38	81	4	4263	·4474
+ 7	243	11	4406	·4432	43	86	4	4000	·4540
10	239	11	5667	·4141	49	86	4	3762	·4599
16	238	11	5667	·4142	51	33	1	2448	·4949
18	358	16	5800	·4105	54	36	2	923	·5498
20	355	16	5800	·4105	60	37	2	910	·5505
				SECOND SERIES.					
36	39	2	923	·5493	79	129	6	5250	·4241
39	226	10	1183	·5371	81	89	4	4747	·4358
44	221	10	1158	·5382	87	93	4	4348	·4453
46	250	11	1223	·5355	94	93	4	4348	·4453
51	244	11	1198	·5365	96	70	3	3651	·4630
53	267	12	1232	·5348	97	70	3	3256	·4732
59	265	12	1227	·5351	104	74	3	2031	·5062
60	303	13	1288	·5322	115	76	3	1695	·5172
63	322	14	1326	·5306	120	75	3	1480	·5250
64	317	14	5667	·4138	122	49	2	920	·5500
73	299	13	5712	·4128	127	52	2	905	·5508
75	127	6	5250	·4241					
				THIRD SERIES.					
9	38	2	910	·5504	21	131	6	1024	·5447
11	135	6	1092	·5444	23	345	15	5450	·4184

84. *Liquid-solid isothermal at 90°.*—Two independent series of results are given in Table 40. In consequence of slight variation of the artificial atmosphere, the temperature of the first is somewhat below that of the second. Thus in series I there is some lack of coincidence in the liquid "on" and "off" march, whereas the two are identical in series II.

TABLE 40.—*Isothermals of naphthalene at $\theta = 90°$, referred to ·55^{cm3} at the normal melting point.*

Time.	Pressure.	$kp \times 10^3$.	R.	Volume.	Time.	Pressure.	$kp \times 10^3$.	R.	Volume.
m.	*Atm.*		*Ohms.*	*cm³*	*m.*	*Atm.*		*Ohms.*	*cm³*
−10	83	4	845	·5502	33	346	16	5055	·4205
−8	83	4	812	·5504	34	287	13	4435	·4357
−6	257	12	1049	·5392	36	273	12	4051	·4455
−2	238	11	1016	·5410	41	277	13	3514	·4597
0	434	19	1247	·5296	47	274	12	2969	·4736
+5	425	19	1217	·5309	51	275	12	2677	·4831
7	549	25	5250	·4147	59	272	12	1950	·5042
20	527	24	5329	·4130	62	190	8	923	·5457
22	445	20	5211	·4163	67	192	8	923	·5457
27	446	20	5173	·4172	70	68	3	790	·5532
28	375	17	5100	·4193					

Digitized by Google

TABLE 40.—*Isothermals of naphthalene at $\vartheta = 90°$, referred to ·55^{cm3} at the normal melting point*—Continued.

SECOND SERIES, SAME ADJUSTMENT.									
Time.	Pressure.	$kp \times 10^3$.	*R.*	Volume.	Time.	Pressure.	$kp \times 10^3$.	*R.*	Volume.
m.	*Atm.*		*Ohms.*	cm^3	*m.*	*Atm.*		*Ohms.*	cm^3
16	57	3	773	·5542	60	316	14	4618	·4311
18	231	10	972	·5432	65	322	14	4555	·4326
24	222	10	957	·5439	67	280	13	3855	·4504
26	422	19	1188	·5322	73	283	13	2333	·4929
31	406	18	1155	·5338	76	283	13	1985	·5028
33	490	22	1247	·5293	81	278	13	1618	·5152
40	474	21	1232	·5302	83	175	8	897	·5472
42	507	23	1258	·5292	89	179	8	902	·5468
44	532	24	1288	·5276	91	81	4	793	·5530
46	555	25	5250	·4147	95	83	4	802	·5524
57	514	24	5290	·4139					

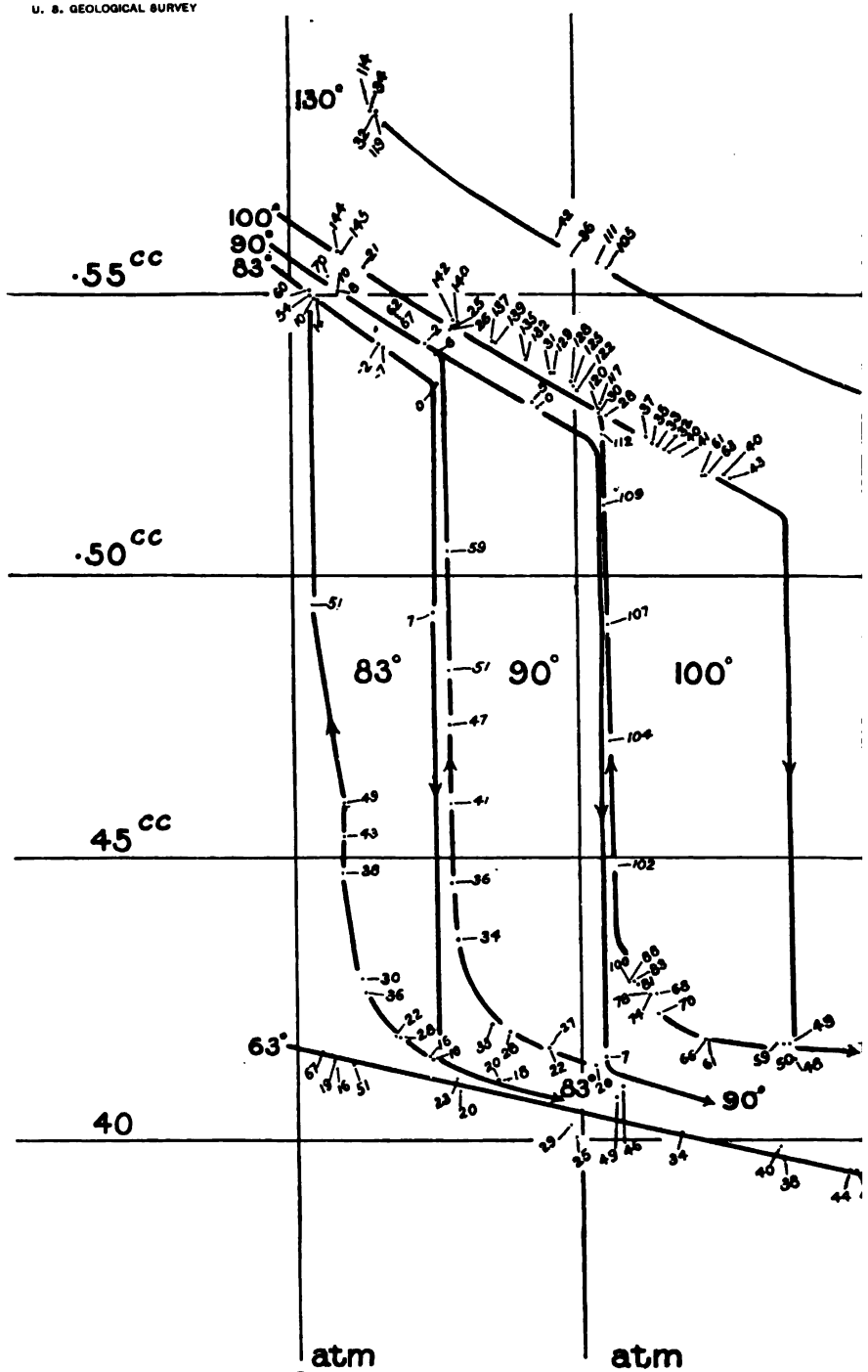
85. *Liquid-solid isothermals at 100°.*—Table 41 contains four independent series of results, together with some preliminary measurements. These are my earliest result with the above tube and are therefore in greater number. The liquid isothermals should be identical in the "on" and "off" marches. This is, as a rule, very nearly the case, the preliminary series and "on" march of the first alone lying below the others. In the latter the telephone used was more sensitive than in the ormer.

TABLE 41.—*Isothermals of naphthalene at $\vartheta = 100°$, referred to ·55^{cm3} at the normal melting point.*

PRELIMINARY MEASUREMENTS.				
Time.	Pressure.	$kp \times 10^3$.	*R.*	Volume.
m.	*Atm.*		*Ohms.*	cm^3.
5	170	7	780	·5499
10	170	7	780	·5499
13	384	7	1006	·5367
15	355	16	984	·5380
17	503	27	1225	·5255
19	558	25	1209	·5264
21	636	28	1277	·5232
23	610	27	1261	·5239
24	651	29	1301	·5221
27	688	31	1336	·5204
30	196	9	812	·5480
32	176	8	783	·5497
TUBE AGAIN ADJUSTED. FIRST SERIES.				
21	130	6	707	(·5545)
25	280	13	884	·5436
26	284	13	876	·5441
28	557	25	1169	·5283
30	540	24	1156	·5289
32	655	29	1296	·5222
33	642	29	1279	·5230
35	636	29	1274	·5232
37	622	28	1247	·5245
40	662	30	1307	·5218
41	688	31	1322	·5210
43	769	35	1405	·5172
44	759	35	1392	·5178
48	875	39	4840	·4137
49	862	39	4720	·4169
50	856	39	4720	·4169
59	843	38	4720	·4170
61	720	32	4720	·4177
66	720	32	4720	·4177
68	631	28	4420	·4249
70	633	28	4560	·4225
74	623	28	4420	·4259
78	611	27	4420	·4260
81	600	27	4370	·4274
83	595	27	4370	·4274
88	593	27	4280	·4296
97	592	27	4350	·4278
100	587	26	4350	·4279
102	561	25	3600	·4483
104	556	25	2840	·4708
107	553	25	2150	·4915
109	549	25	1530	·5127
112	545	24	1240	·5250
117	544	24	1120	·5307
120	542	24	1140	·5298
122	503	22	1080	·5127
125	499	22	1068	·5335
128	497	22	1050	·5343
129	461	21	1019	·5360
131	458	21	1019	·5360
132	417	19	978	·5381
135	413	18	978	·5381
137	358	16	921	·5414
139	358	16	924	·5412
140	296	13	862	·5449
142	296	13	856	·5447
144	87	4	660	(·5575)
145	87	4	656	(·5578)
SECOND SERIES. SAME ADJUSTMENT.				
20	116	5	667	(·5575)
27	116	5	667	(·5575)
29	281	13	852	·5455

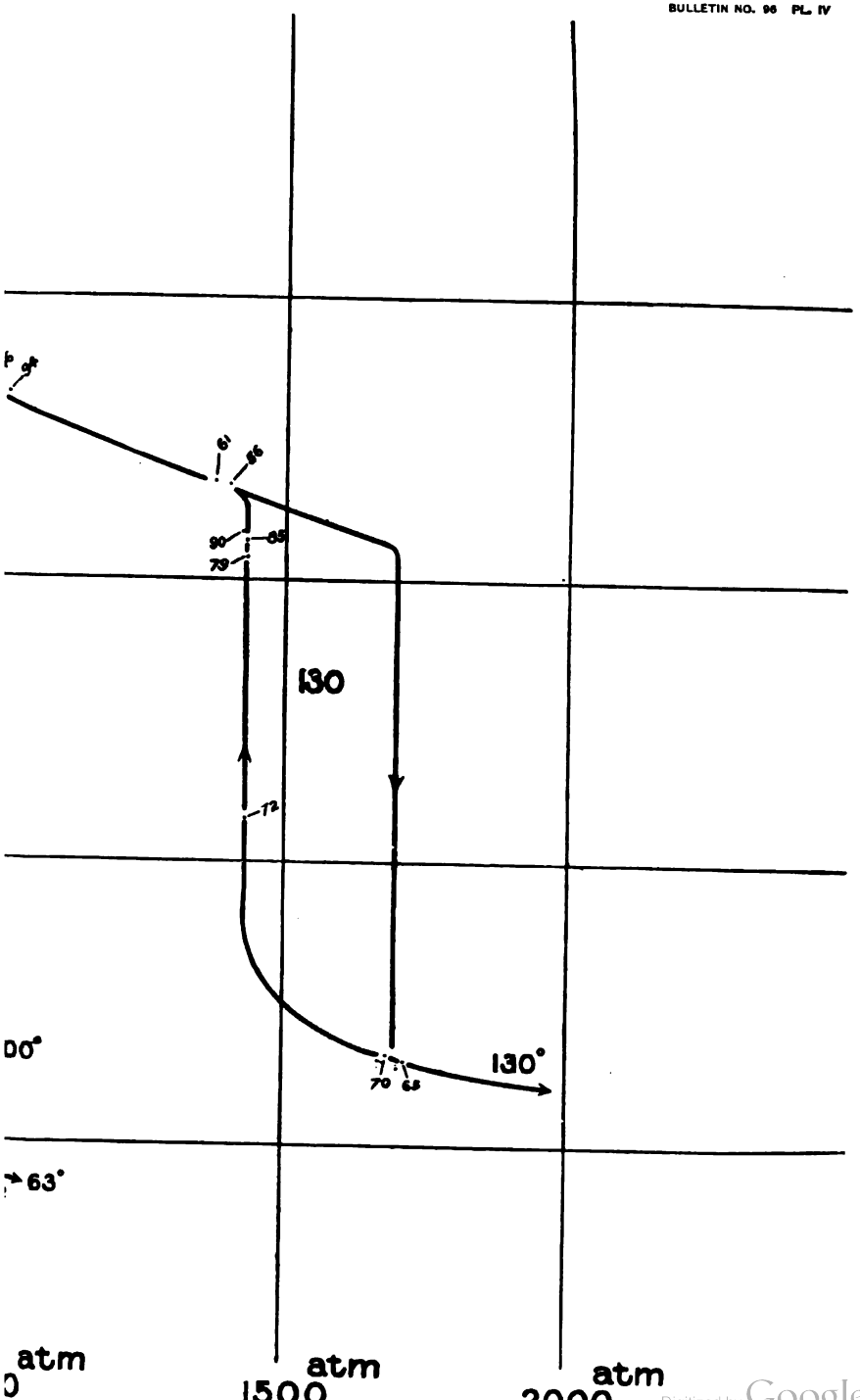
Digitized by Google

Digitized by Google



Digitized by Google

FUSION ISOTHERMALS OF



NAPHTHALENE. FIRST SET.

Digitized by Google

Digitized by Google

TABLE 41.—*Isothermals of naphthalene at* $\vartheta = 100°$, *referred to* $\cdot 55^{cm3}$ *at the normal melting point*—Continued.

Time.	Pressure.	$kp \times 10^3$.	R.	Volume.
m.	*Atm.*		*Ohms.*	cm^3.
36	274	12	835	·5464
45	460	21	1020	·5360
47	670	30	1223	·5255
53	653	29	1198	·5266
56	795	35	1331	·5204
63	766	34	1300	·5219
64	808	36	1353	·5195
69	797	36	1353	·5195
75	780	35	1336	·5202
76	818	37	1370	·5185
85	813	36	1370	·5187
91	785	35	1336	·5202
93	856	39	1415	·5167
102	850	38	1410	·5169
107	820	37	1370	·5185
108	908	41	1439	·5155
116	888	40	1439	·5156
121	890	40	1439	·5155
122	921	41	4814	·4141
133	914	41	4882	·4125
148	906	41	4882	·4124
150	769	35	4714	·4175
157	772	35	4714	·4175
159	644	29	4556	·4224
165	652	29	4556	·4224
167	560	25	3808	·4425
168	560	25	3202	·4599
169	562	25	2846	·4707
171	558	25	2279	·4877
173	558	25	1889	·5000
176	558	25	1600	·5102
178	558	25	1416	·5175
180	557	25	1300	·5224
184	552	25	1174	·5280
187	553	25	1160	·5287
208	553	25	1158	·5288
213	546	25	1160	·5287
216	429	19	988	·5375
225	430	19	992	·5375
227	287	13	845	·5459
235	292	13	852	·5454
237	81	4	645	(·5585)
244	86	4	650	(·5583)
THIRD SERIES. SAME ADJUSTMENT.				
7	87	4	653	(·5583)
12	88	4	653	(·5583)
15	274	12	838	·5462
20	267	12	828	·5468
22	489	22	1045	·5345
28	476	21	1008	·5365
31	666	30	1208	·5262
38	649	29	1220	·5256
41	837	38	1375	·5185
47	820	37	1359	·5191
49	874	39	4814	·4143
56	864	39	4883	·4126
70	770	35	4814	·4149
81	760	34	4780	·4159
83	675	30	4714	·4181
88	677	31	4682	·4187
90	578	26	4000	·4371
93	581	26	3975	·4377
96	581	26	3608	·4480
100	580	26	3525	·4503
102	571	26	3255	·4581
107	574	26	2732	·4739
115	569	26	2390	·4845
123	571	26	2087	·4934
131	566	25	1829	·5018
133	557	25	1611	·5097
135	547	25	1380	·5189
136	490	22	1070	·5333
138	484	22	1033	·5351
139	276	13	835	·5464
141	77	4	631	(·5600)
143	80	4	638	(·5590)
FOURTH SERIES. SAME ADJUSTMENT.				
6	72	3	620	(·5605)
9	72	3	622	(·5605)
13	266	12	828	·5468
19	257	12	805	·5481
21	252	11	802	·5483
23	451	20	1008	·5365
33	418	19	957	·5393
36	689	31	1247	.5243
42	642	29	1169	.5280
44	818	37	1353	.5194
50	811	36	1331	.5204
57	853	38	1364	.5188
59	903	40	4882	.4125
65	900	40	4917	.4115
67	1018	45	4988	.4089
73	1005	45	5024	.4080
74	879	40	4882	.4125
79	865	39	4814	.4143
81	690	31	4587	.4213
85	694	31	4587	.4213
87	575	26	4000	.4371
93	581	26	3785	.4430
99	549	25	1631	.5090
105	549	25	1165	.5280
110	539	24	1123	.5306
112	488	22	1041	.5347
120	484	22	1012	.5363
122	294	13	832	.5465
127	295	13	835	.5463
129	89	4	634	(.5595)
135	97	4	647	(.5585)

86. *Liquid solid isothermals at 117°.*—Table 42 contains a series of results. The vapor bath in this case was filled with amyl alcohol, from which the water was not extracted. Hence the peculiarly broken isothermal obtained is in correspondence with the known inconstancy of temperature along the vertical. This feature is, however, of considerable interest, and throws light on certain characters of the other isothermals, inasmuch as it shows the behavior in case of partial solidification.

Digitized by Google

TABLE 42.—*Isothermals of naphthalene at* $\Theta = 117°$, *referred to* $\cdot 55^{cms}$ *at the normal melting point.*

Time.	Pressure.	$kp \times 10^3$	*R.*	Volume.	Time.	Pressure.	$kp \times 10^3$	*R.*	Volume.
m.	*atm.*		*ohms.*	cm^3.	*m.*	*atm.*		*ohms.*	cm^3.
4	86	4	408	(·5709)	64	1317	59	4263	·4094
5	86	4	408	(·5709)	66	1055	47	3546	·4325
7	277	13	600	(·5547)	72	1053	47	2448	·4692
12	272	13	585	(·5549)	75	1051	47	2279	·4749
14	496	22	784	·5111	81	1054	47	2175	·4786
20	468	21	740	·5439	84	877	40	1253	·5149
22	689	31	946	·5309	90	877	40	1198	·5174
27	651	29	894	·5339	91	701	31	953	·5307
29	910	41	1123	·5210	95	707	31	938	·5314
35	895	40	1097	·5224	97	517	23	760	·5426
37	1092	49	2257	·4756	102	523	23	765	·5421
39	1086	49	2771	·4579	103	285	13	565	(·5571)
50	1068	48	2704	·4601	107	290	13	572	(·5561)
52	1254	56	4208	·4114	109	96	5	412	(·5699)
58	1226	55	4208	·4115	115	100	5	414	(·5699)
59	1326	60	4263	·4091					

87. *Liquid solid isothermals at 130°.*—Table 43, finally, contains four series of results obtained at 130°. The vapor bath in this case contained amyl alcohol, thoroughly dried by copious distillations. Slight differences in the liquid "on" and "off" march are only apparent in the last series. The temperature of the third series was about 129.6°.

TABLE 43.—*Isometrics of naphthalene at* $\Theta = 130°$, *referred to* $\cdot 55^{cms}$ *at the normal melting point.*

FIRST SERIES. SAME ADJUSTMENT.				
Time.	$kp \times 10^3$	Pressure.	*R.*	Volume.
m.		*atm.*	*ohms.*	cm^3.
32	7	151	272	(·5821)
34	7	146	270	(·5821)
36	22	496	522	(·5566)
42	21	461	493	(·5591)
46	45	908	862	·5316
52	45	978	845	·5328
56	63	1403	1119	·5166
61	63	1379	1105	·5171
65	76	1713	3808	·4148
70	76	1686	3785	·4156
72	63	1432	2600	·4578
79	63	1438	1392	·5039
85	63	1433	1326	·5069
90	63	1423	1294	·5081
94	45	1013	847	·5326
102	41	897	786	·5365
105	25	588	548	(·5546)
111	24	540	538	(·5551)
114	7	145	266	(·5821)
119	7	154	275	(·5816)

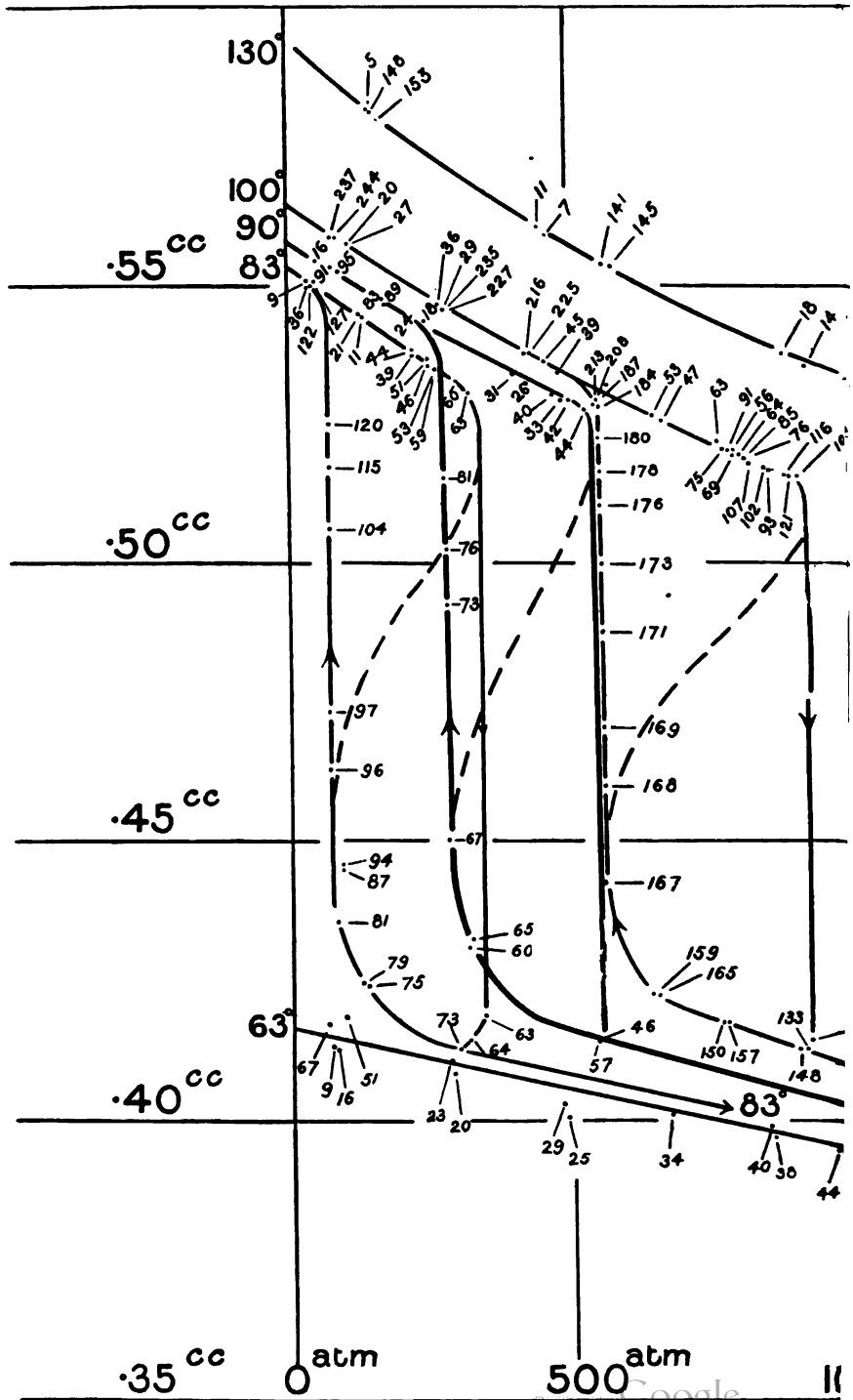
SECOND SERIES. SAME ADJUSTMENT.				
5	7	151	276	(·5811)
7	21	464	495	(·5586)
11	20	451	484	(·5601)
14	41	921	808	·5351
18	40	881	770	·5378
35	58	1338	1057	·5200
37	59	1336	1057	·5200
57	65	1464	1132	·5158
59	65	1459	1132	·5158
61	74	1581	1223	·5109
63	74	1656	1278	·5083
64	74	1651	1262	·5091

Time.	$kp \times 10^3$	Pressure.	*R.*	Volume.
m.		*atm.*	*ohms.*	cm^3.
65	78	1737	1329	·5057
68	78	1723	1320	·5061
71	81	1794	3878	·4119
76	79	1777	3926	·4106
78	85	1907	3926	·4099
84	85	1880	3950	·4091
86	72	1574	3695	·4190
96	72	1575	3695	·4190
98	65	1463	2876	·4480
106	65	1463	1690	·4914
113	65	1458	1481	·5000
123	65	1456	1490	·4996
125	56	1245	1021	·5220
131	56	1244	1021	·5221
135	44	990	845	·5327
139	44	994	850	·5325
141	25	585	565	(·5536)
145	26	580	570	(·5531)
148	7	155	275	(·5811)
153	7	168	289	(·5796)

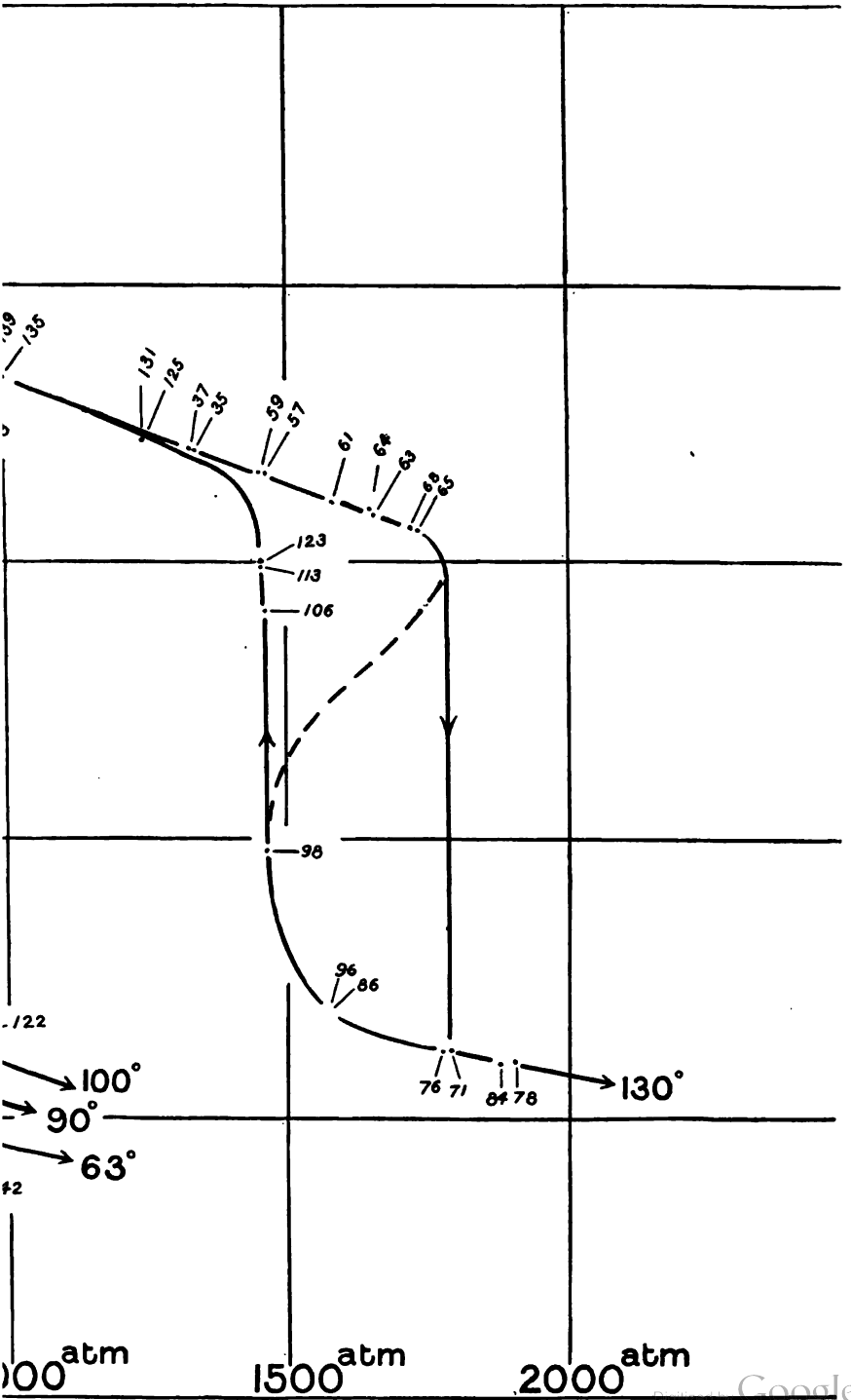
THIRD SERIES. SAME ADJUSTMENT.				
9	6	135	263	(·5831)
12	6	134	263	(·5831)
15	21	468	517	(·5571)
22	21	456	504	(·5581)
28	44	971	845	·5327
31	43	960	825	·5341
34	65	1467	1164	·5143
43	63	1420	1114	·5168
45	72	1579	1242	·5101
50	70	1564	1212	·5116
53	74	1665	3739	·4178
59	74	1632	3762	·4166
61	81	1794	3831	·4135
63	81	1784	3831	·4135
66	70	1564	3651	·4206

Digitized by Google

Digitized by Google



Digitized by Google



NAPHTHALENE. SECOND SET.

Digitized by Google

Digitized by Google

TABLE 43.—*Isometrics of naphthalene at $\theta = 130°$, referred to ·55 cm³ at the normal melting point*—Continued.

Time.	$kp \times 10^3$	Pressure.	R.	Volume.	Time.	$kp \times 10^3$	Pressure.	R.	Volume.
m.		*atm.*	*ohms.*	*cm³*	*m.*		*atm.*	*ohms.*	*cm³*
75	70	1558	3651	·4206	57	28	626	653	·5465
77	67	1484	3405	·4291	63	27	611	634	·5479
83	67	1509	3310	·4324	67	36	801	770	·5379
85	63	1412	2334	·4670	72	36	789	755	·5389
91	63	1416	1217	·5117	74	45	1022	930	·5276
109	63	1412	1198	·5126	84	43	956	845	·5329
105	47	1044	855	·5319	87	54	1215	1050	·5206
111	47	1044	865	·5312	90	54	1200	1033	·5214
113	26	576	560	(·5536)	92	65	1432	1208	·5123
120	26	584	560	(·5531)	96	63	1412	1174	·5139
122	7	146	266	(·5821)	98	74	1634	1331	·5059
128	7	160	279	(·5801)	104	72	1606	1320	·5065
					108	72	1603	1320	·5067
FOURTH SERIES.					112	54	1196	1029	·5217
					118	54	1199	985	·5240
					119	39	859	755	·5387
					124	39	862	765	·5381
45	9	196	320	(·5769)	126	22	498	515	(·5571)
48	9	196	320	(·5769)	127	22	503	525	(·5561)
50	19	427	490	(·5591)	134	7	151	282	(·5781)
55	19	416	480	(·5601)	140	7	160	290	(·5781)

DEDUCTIONS.

88. *Graphic construction.*—To obtain a comprehensive survey over this series of individual data, it will be necessary to resort to the pictorial method and represent volume as a function of pressure, under successive conditions of constant temperature. Moreover it will be expedient to represent the whole group of first series on a single chart, the second series on another chart, etc., and thus obtain about four distinct sets of results, covering the whole interval 60° to 130°, and about 1,900 atmospheres. This has been done in Pls. IV, V, VI, and VII, in which the ordinates are volumes (the fiducial volume being the ·5524^{cm3} at 80°, arbitrarily chosen), the abscissas are pressures, and in which the temperatures of the isothermals are inscribed at the beginning and end of each curve. Finally the dates or times in minutes at which the individual observations were made are all given by small numerals attached to the points. Thus it is easy to know at once whether an observation was taken during the "on" march or the "off" march of pressure; but to further facilitate inspection arrows are subjoined to the contours of the curves, showing their drift. It is seen from the figures that the solid seems to be comparable as regards compressibility with the liquid, but on this point I shall not now lay much stress, for reasons repeatedly stated in the above paragraphs, §§ 70, 82.

89. *Hysteresis.*—The inherent character of all these curves is pronouncedly cyclic. The isothermal pressure necessary to solidify naphthalene being at all temperatures decidedly in excess of the pressure at which it again liquefies. Then the results which I obtained in other experiments and with other substances some time ago[1] are thus emphat-

[1] Am. Jour. Sci., vol. 38, 1890, p. 408. The full paper and the deductions there made are as yet unpublished.

Digitized by Google

ically corroborated. Evidences of the thoroughly static character of these phenomena are abundant and obtained by observing the times of successive points. I need only mention solid isothermal, 100° Pl. IV, where I waited from 50^m to 100^m at a pressure below the solidifying point of the liquid without obtaining fusion; whereas after this with only a slight further reduction of pressure fusion sets in and is complete between 101^m and 112^m; liquid isothermal, 100°, Pl. V, where I waited from 47^m to 121^m at a pressure greater than that at which fusion of the solid takes place without obtaining solidification, which, however, sets in at once (121^m 122^m) when the pressure interval is only slightly increased; same plate solid isothermal 130°, I waited from 86^m to 96^m at a pressure below the solidifying point without any change of volume or fusion whatever; solid isothermal, 130° Pl. VI, where I waited from 66^m to 83^m without obtaining fusion, and from 66^m to 75 ^{m} without appreciable change of volume; liquid isothermal, 100°, Pl. VII, where I waited from 36^m to 90^m without obtaining solidification, and from 74^m to 87^m on the solid isothermal without obtaining fusion, etc. If high temperature conditions are unfavorable to lag, the results at 130° are specially good evidence in favor of the point of view taken. I have already pointed out[1] that it is a phenomenon inherent in the passage from one molecular condition to another which lies at the root of all manifestations of hysteresis, whether observed electrically (Cohn, Ewing, Schumann) or magnetically (Warburg, Ewing), or as a purely mechanical result in my work,[2] during fusion, as above, during solution, § 95, etc.

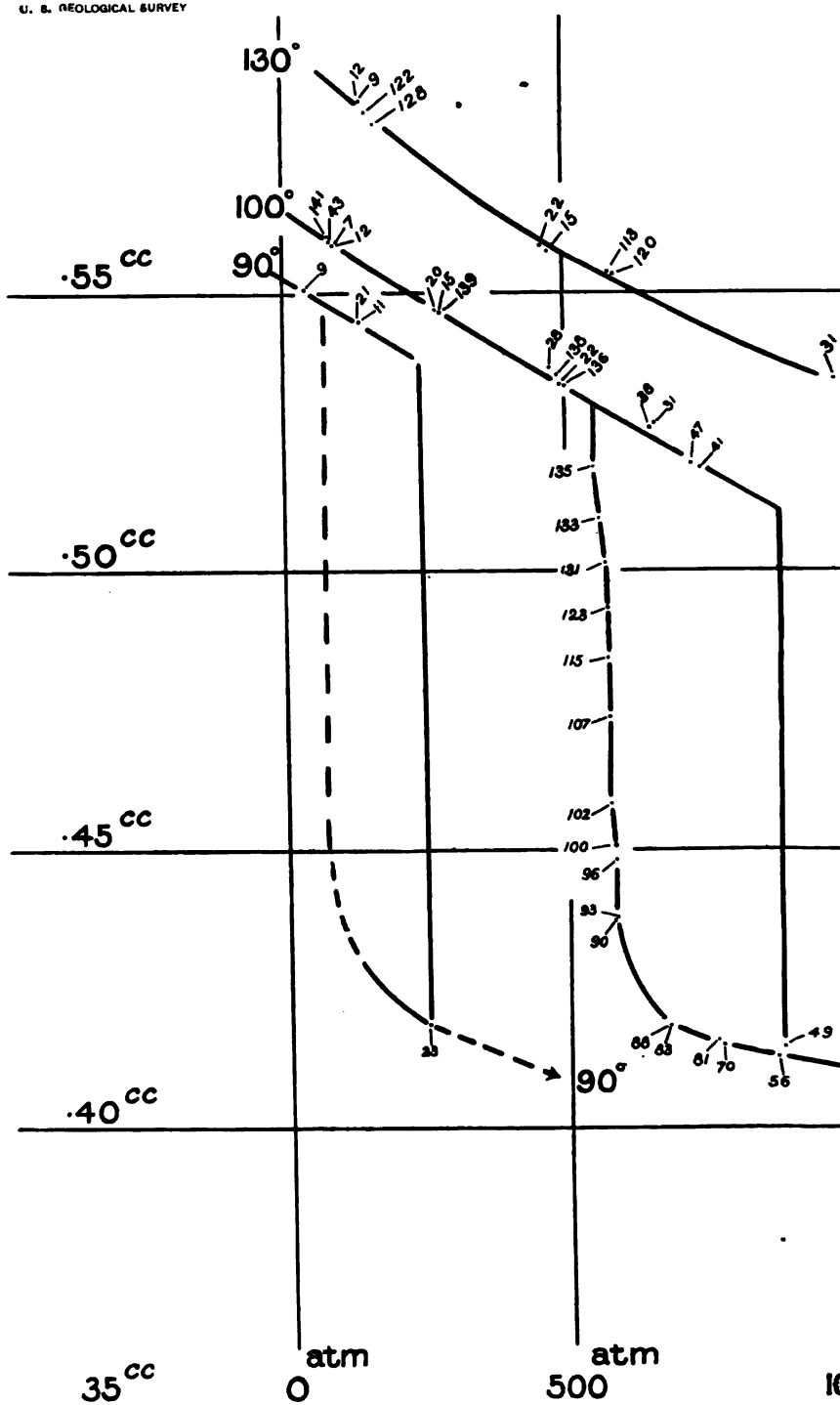
90. *James Thomson's double inflections.*—Solidification almost always sets in at once. This is what one should expect, for, if there be condensation or crystallization at any point, it will form a nucleus for which the whole column will be solidified. Only in one case (Pl. V, liquid isothermal 83°, 60^m to 63^m) did I obtain evidences of curvature, whereas in Pl. IV, at the same temperature, the whole path, though observable (0^m, 7^m, 10^m), is precipitous.

The reverse of this holds true in case of fusion. Here the initial or stable contours of James Thomson's circumflexures are always marked. It is true that fusion rarely takes place instantaneously, because of the difficulty in supplying heat fast enough. Hence it might be plausibly argued that the fusion contours are necessarily more gradual than the solidification contours. It is also supposible that, if temperature be not quite identical throughout the height of the column of substance, fusion will first take place at the hotter planes below and proceed thence to the top. This state of things I have actually observed in glass capillary tubes when the vapor baths were imperfect. In the present experiments, however, the phenomenon occurs with the same uniformity at all temperatures and is quite as pronounced in a

[1] Am. Journal, l. c.; Phil. Mag. (5), vol. 31, 1891, p. 27.
[2] Chapter III, above.

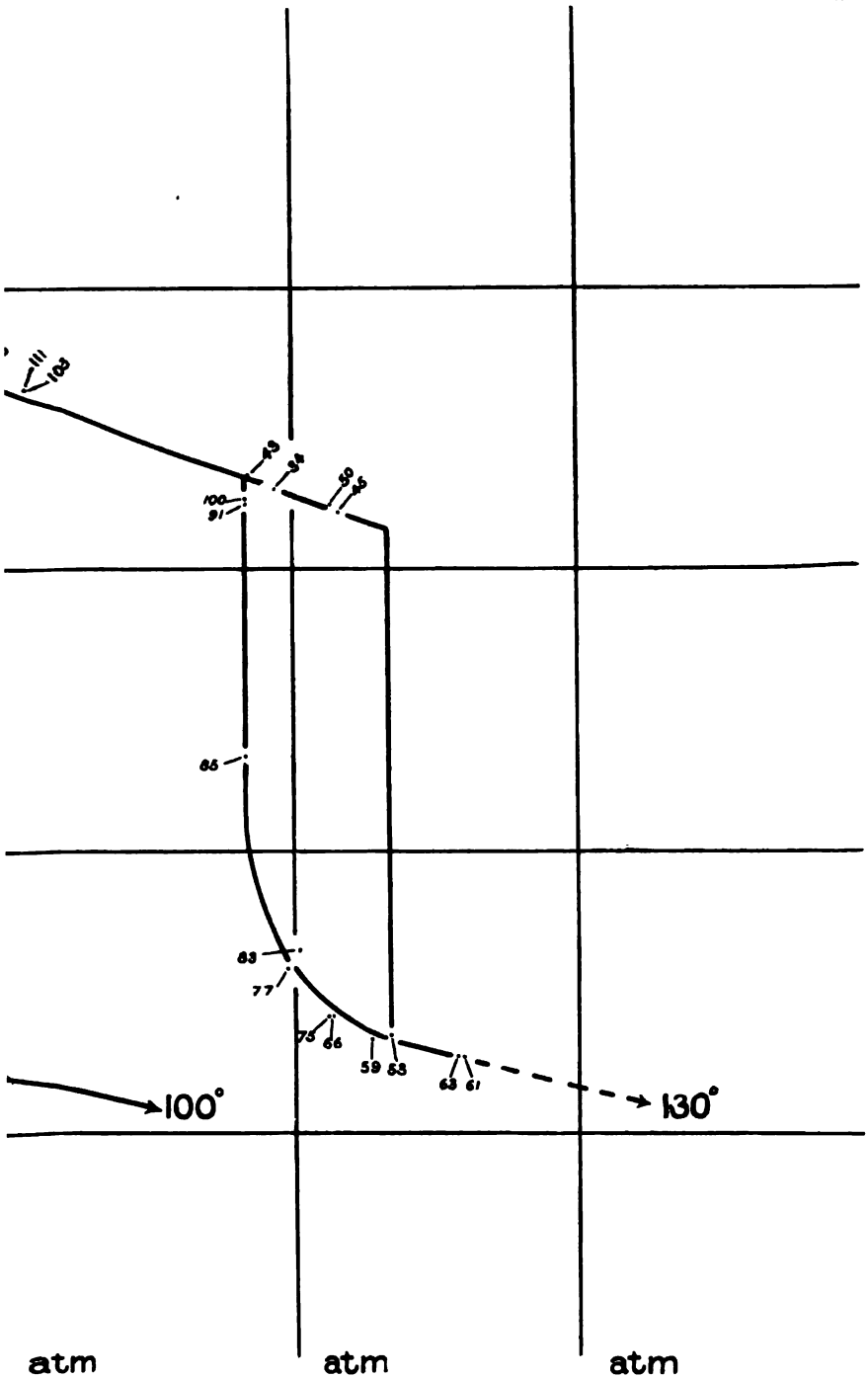
Digitized by Google

Digitized by Google



FUSION ISOTHERMALS OF

Digitized by Google



APHTHALENE. THIRD SET.

Digitized by Google

Digitized by Google

steam bath. Moreover the column is not above 10^{cm} long. Hence, taking this into account in connection with the evidence cited in the foregoing paragraph (89), I conclude that the initial solid contours are static, and hence regard them as evidencing James Thomson's[1] well-known inference relative to the doubly inflected contours of the isothermals accompanying change of physical state. When fusion actually sets in the phenomenon is no longer observable, for the physical parts of the substance now exist in widely different thermal states.

Here I may expediently point out the advantages gained by operating in a thin shell of substance (see Fig. 13 and Pl. III), the heat within which is rapidly dissipated. The conditions, therefore are specially favorable for isothermal work.

91. *The characteristic specific volumes.*—Mere inspection of the charts, Pls. IV to VII, shows that the volume at which solidification takes place decreases with temperature, and the volume after solidification either increases or remains stationary in value. In Table 44 I have inscribed the corresponding values of pressure and volume, observed at the solidification points, in each of the four series; and in Pl. VIII these data have been plotted, volumes being the abscissæ and pressures the ordinates. To distinguish the points they are surrounded by little circles to which the number of the series is attached, and the pressures are given on the right side of the diagram.

TABLE 44.—*Volumes solid and liquid at the solidifying points, varying with the pressure.**

Series.	Temperature 83°.		Temperature 90°.		Temperature 117°.	Temperature 100°.		Temperature 130°.	
	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.	Solid pressure. Solid volume.	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.
I.	260	260	550	550	.....	875	875	1720	1720
	·415	·534	·413	·523	.....	·416	·510	·415	·505
II.	320	320	555	550	.....	920	920	1790	1790
	·415	·530	·415	·527	.....	·413	·515	·412	·505
III.	345	345	550	.....	.....	870	870	1665	1665
	.....	.....	·418	.....	.....	·413	·510	·417	·507
IV.	.....	.....	.....	.....	.....	900	900	1720	1720
	.....	.....	.....	.....	·415	·412	·517	.....	·505

* See remarks on Table 46.

A similar and equally important table may be deduced by finding the values of the characteristic volumes at the successive melting points. These are inscribed in Table 45, on the plan of Table 44.

[1] J. Thomson: Phil. Mag. (4), vol. 42, 1872, p. 227.

Digitized by Google

TABLE 45.—*Volumes solid and liquid at the melting points, varying with pressure.**

Series.	Temperature 83°.		Temperature 90°.		Temperature 117°.	Temperature 100°.		Temperature 130°.	
	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.	Solid pressure. Solid volume. Liquid volume.	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.	Solid pressure. Solid volume.	Liquid pressure. Liquid volume.
1	80	80	275	275	.....	560	560	1430	1430
	·435	·547	·425	·540	.....	·440	·528	·435	·515
2	80	80	280	280	.....	560	560	1465	1465
	·450	·548	·440	·541	.....	·435	·531	·430	·515
3	.....	.....	.....	.....	.....	580	580	1410	1410
	.....	.....	.....	.....	.....	·440	·528	·440	·517
4	.....	.....	.....	.....	1050	570	570	.....	.....
	.....	.....	.....	.....	·430	·440	·531	.....	.....
	.....	.....	.....	.....	·515				

* See remarks on Table 46.

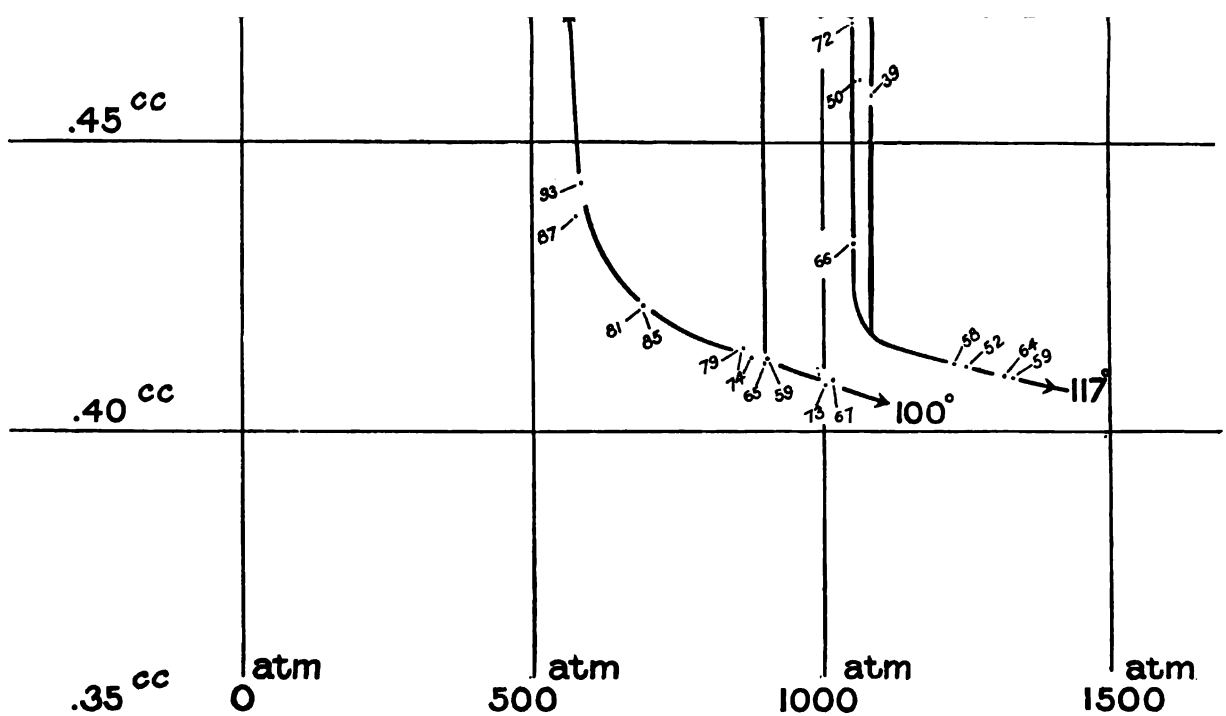
If these data be inscribed in a chart like Pl. VIII, both the solid and the liquid volumes will closely resemble the curves already mapped out for solidifying point; but since the solid volumes can obviously only be approximately given, and since the liquid volumes contain no new feature, I omit them to avoid confusing the figure.

A noticeable part of this diagram is the close accordance of the three groups of points between 0 and 1,000 atmospheres, during which measurements vapor of water was the medium of constant temperature, as compared with the one group of points between 1,000 and 2,000 atmospheres, where vapor amyl alcohol was used. I account for this by supposing the solidification in the latter case (130°) to have been premature, a result to be associated with insufficient constancy of the vapor bath (§ 70, 86, 89), hence the liquid volumes found are too large. There may, however, have been some gradual change in the contents of the tube, which in the lapse of time became appreciable (§76, 81). Thus the zinc gradually deposited by the intermittent currents in the mercury, the possible detachment of the end of the mercury thread in *hk* (Fig. 13) after repeated motion back and forth, changes in the quality of the solution of zinc sulphate, etc., would produce a shifting of the volume constants and a result like that observed in Pl. VIII. Further experiments must decide this point. Regarding the solid volumes, it is clear at once that no device can define them as accurately as the liquid volumes, and the degree of coincidence attained is one of the valuable accomplishments of the present method.

To summarize, therefore, I have in Pl. VIII placed chief reliance on the water points (0 to 1,000 atmospheres) and drawn the locus accordingly.

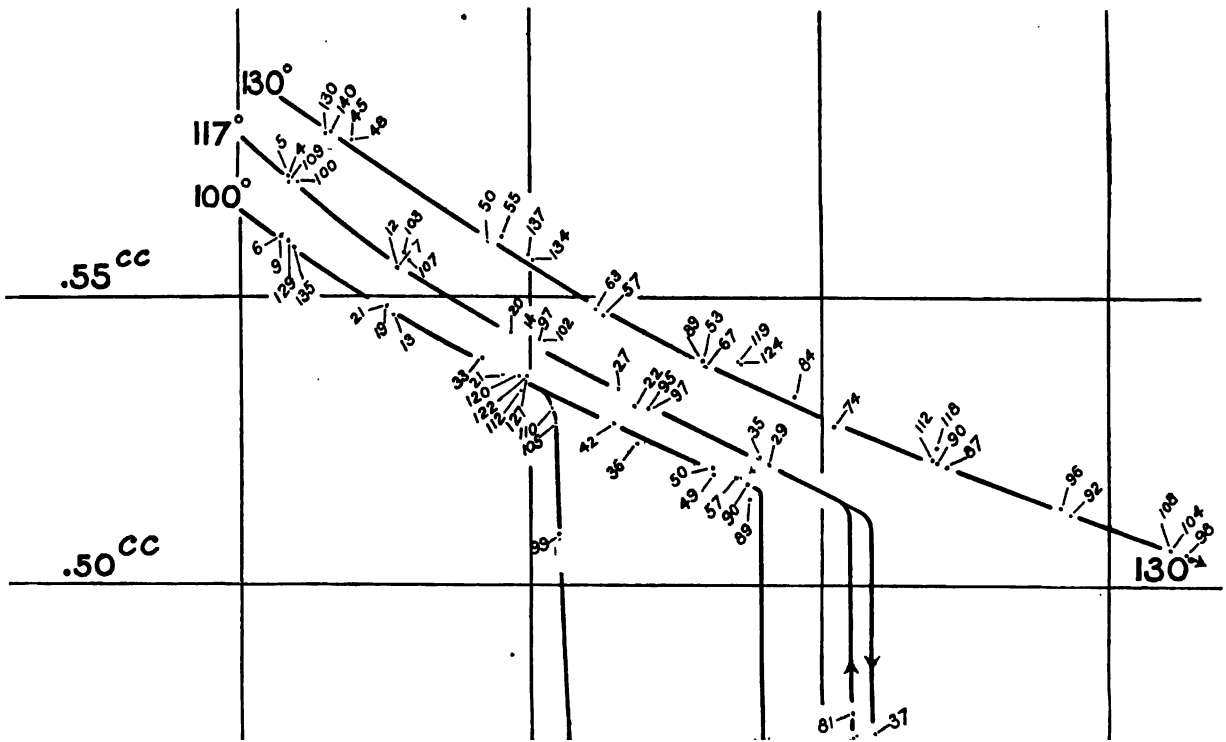
92. *Critical point.*—The area inclosed by the figure *a b . . . c d*, supposing *b* and *c* eventually to coalesce, has the same signification as Andrews' area of vapor tensions. The same would be true of the similar figure for the characteristic volumes at the melting points, or

Digitized by Google



FUSION ISOTHERMALS OF NAPHTHALENE. FOURTH SET.

Digitized by Google



Digitized by Google

Digitized by Google

finally to the figure in which the solidification volumes are taken at the solidification points, and the fusion-volumes at the melting points. All of these diagrams point out the probable occurrence of a critical point in the region of positive pressure and reached in the direction of increasing temperature, at which point liquid would pass to solid or solid to liquid without paroxysmal change of volume, and consequently without volume log. This position of this point may be conjectured to lie at several hundred degrees centigrade and several thousand atmospheres, naphthalene being the material operated on.

93. ***Solidifying points and melting points.***—The cycles as depicted in Pls. IV to VII have two prominent characteristics: They gradually decrease in vertical extent from left to right, and they gradually decrease in lateral extent toward both sides of the chart. Each of these qualities throws important light on the phenomena as a whole.

Table 46 gives the numerical values of the pressures corresponding to solidification and to fusion at the different temperatures, together with other information of importance, as sharply as the statement can be made. Let the solidifying points and the melting points be constructed as a function of pressure. This is done in Pl. VIII, and the points form a long spindle-shaped figure running diagonally across the chart. Points obtained from all the four sets of results (Pls. IV to VII) are inscribed and these points are numbered to show the series to which they belong. The parts of the curves actually observed are given in full lines and the inferential prolongations in dotted lines.

From the nature of the case the solidification points can not be sharply measured. (§ 89.) Thus, if the temperature of the column be not uniform, (and in case of an ebullition liquid of small specific heat and possibly not homogeneous in composition, the tube is sure to be hotter at the bottom than at the top), the colder parts will solidify first, and at once induce solidification throughout the whole length of the column. This is markedly shown in the isothermal for 117°, and given in Pl. VII, where the solidifying and fusing points are practically in coincidence. (§ 86.) Similarly all jarring and percussion, too rapid increase of pressure, a vibratile wire running through the column as in some of my earlier work, etc., will cause the whole labile framework to topple into solidification. Hence the solidifying point must be fairly *crept upon* and surprised, as it were, and hence my present results, in which these precautions were taken, show high solidifying points as compared with my other work. These conditions do not seem to hold in like importance in case of fusion, for the melting points, as a rule, show much greater coincidence.

Digitized by Google

TABLE 46.—*Showing the relation of solidifying point and of melting point with pressure.—Naphthalene.*

Series No.	Temperature 63°.		Temperature 83°.		Temperature 90°.		Temperature 100°.		Temperature 117°.		Temperature 130°.	
	Solid at—	Fusing at—	Solid at—	Fusing at—	Solid at—	Fusing at—	Solid at—	Fusing at—	Solid at—	Fusing at—	Solid at—	Fusing at—
	Atm.	*Atm.*	*Atm.*	*Atm.*	*Atm.*	*Atm.*	*Atm.*	*Atm.*	*Atm.*	*Atm.*	*Atm.*	*Atm.*
I	.....	(*a*)	*b*260	*c*80	*c*550	*d* 275	*e*875	*d* 560	.....	.....	*e*1720	*f*1430
II	.....	.....	*g*320	80	*d*555	*d* 280	*d*920	*d* 560	.....	.....	*d*1790	*f*1465
III	.....	.....	*e*345	.....	.....	.....	*h*870	*d* 580	.....	.....	*i*1665	*f*1410
IV	.....	.....	.....	.....	.....	.....	*d* 900	*d* 570	*j*1090	*j*1050	*e*1720	.....
k	Factor: Melting point and pressure 80° to 130°, 28·5 atm. °C., or ·0351 °C. / atm. Factor: Solidifying point and pressure 80° to 100°, 36·0 atm./°C., or ·0278 °C./1 atm. Factor: Solidifying point and pressure, 100° to 130°, 29·5 atm./°C., or·0339 1 °C. /1 atm.											

a Negative.
b Not crept upon. First result at <83°, second and third at >83°. Solidification gradual; other solidifications take place at once.
c Fusing very viscously throughout a pressure interval of 50 atmospheres.
d Crept upon.
e Not crept upon.
f Fusion relatively rapid; more nearly resembling the solidification march than is the case at lower temperatures.
g Crept upon. First result at <83°, second and third at >83°. Solidification gradual; other solidifications take place at once.
h Intermediate between *a* and *b*.
i Intermediate between *a* and *b*. Temperature, 129·6°.
j Temperature lower at top than at bottom of the column. Partial fusions. Vapor bath containing aqueous amyl alcohol.
k Chiefly with reference to Series II.

In drawing Pl. VIII I have therefore placed chief reliance on the data of Series II, obtained as they were with the experience of Series I, to guide me. The horizontal breadth of the spindle-shaped area indicates the pressure amount of volume lag corresponding to any temperature.

94. *Transitional point.*—If the two curves be prolonged in the direction of increasing temperature, it is clear that they must eventually coalesce. For, at the critical temperature, liquid will pass to solid and vice versa without paroxysmal change of specific volume, and hence there can be no volume lag.

If the curves be prolonged in the direction of decreasing temperature, then the data emphatically indicate the probable occurrence of an intersection in the region of negative pressure. Beyond the point of intersection the substance would solidify at a lower pressure than that at which it fuses, and fuse at a higher pressure than that at which it solidifies. I believe this observation may be interpreted as follows: The normal type of fusion changes continuously into the ice type of fusion, through a transitional type characterized by the zero of volume lag. The position of this transitional type for naphthalene, so far as I can now discern it, may be placed at, say, 50° and —1,000 atmospheres. It may be noted that with the understanding here laid down, the normal type of fusion is reached from the ice type in the direction of increasing temperature.

Throughout the present chapter I have avoided the discussion of the isopiestics, since I shall consider them in detail in connection with special experiments. It is well to state, however, that the transitional temperature is related to the prospective intersection of the prolonged

Digitized by Google

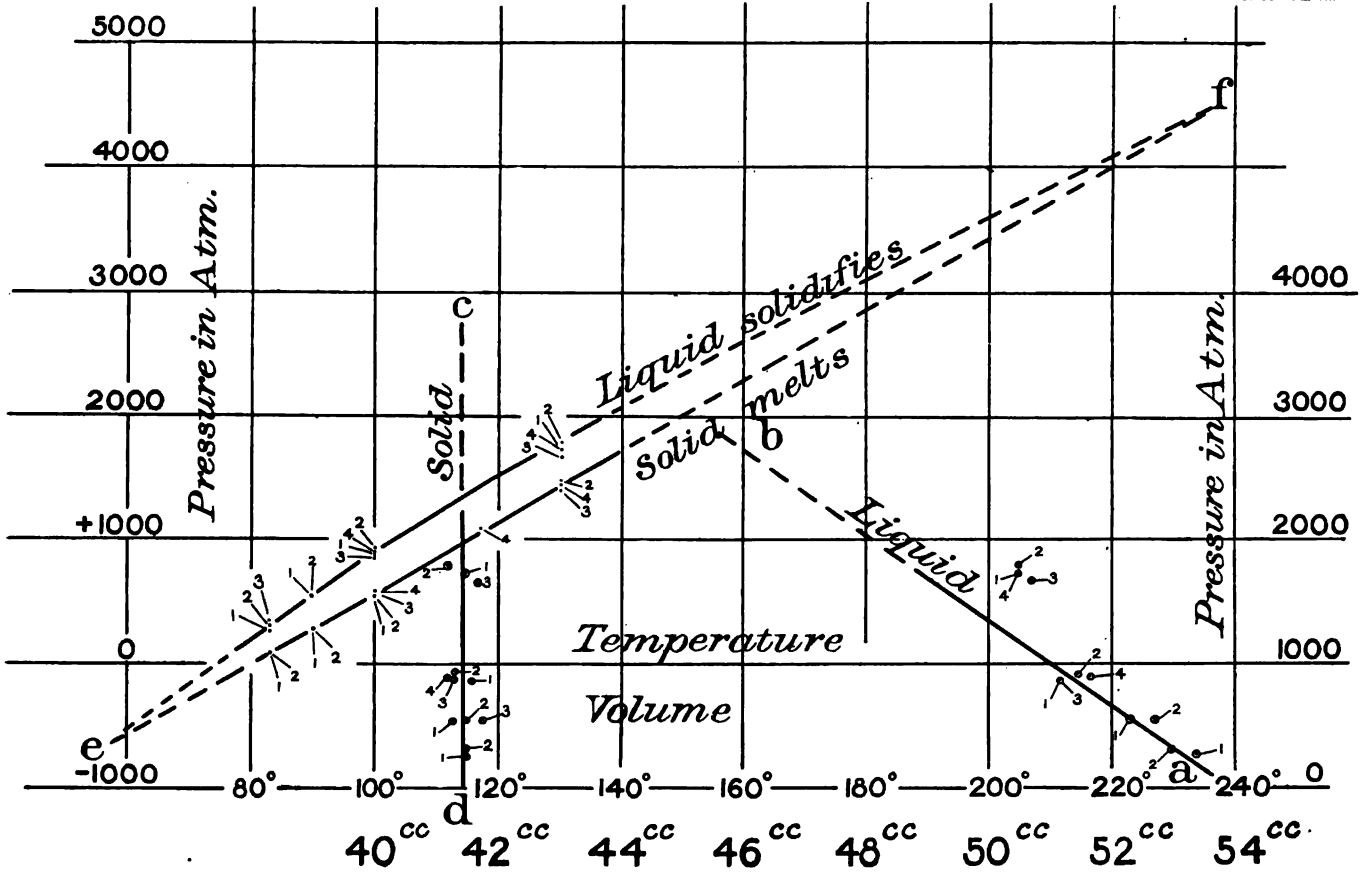


DIAGRAM SHOWING THE CONDITIONS OF FUSION AND SOLIDIFICATION.

Digitized by Google

Digitized by Google

liquid and solid isopiestics, of a given substance, at the same pressure in both cases. Thus a reason why hysteresis may vanish is again suggested. A given substance on one side of the transitional temperature need not necessarily differ molecularly from the same substance on the other side.

Practically only one of the states is attainable, for the other implies an application of negative pressure.

If the chart, Pl. IV, is to represent in diagram a field of isothermals for the ice type, the solid and liquid phases of the chart are to be exchanged. The solid march for the ice type takes place along loci of greater specific volumes and the liquid march along loci of smaller specific volumes. Thus the chart of isothermals must show intersecting loci, identical points corresponding, however, to different molecular states. In other respects the character of the figure need not be modified, supposing always that increase of temperature and pressure be taken in the algebraic sense, so that negative quantities are included. Beyond the transitional point I am therefore tempted to look for the proper critical temperature of the ice type in a region of positive external pressures and in the direction of decreasing temperatures.

Thus, curiously enough, the observer is confronted by *periodic relations*, which in all probability will admit of a chemical interpretation. (§§ 95, 96.)

95. *Solubility and pressure.*—In view of the detailed analogy which holds between many characters of fusion and of solution, much that can be investigated for the simpler of these phenomena (fusion apparently) will be applicable to the other. A substance may be transferred from the solid to the liquid state either by heating it or by dissolving it. In general, excess of temperature or of solvent favor the diminution of viscosity here in question. A liquid on the verge of solidification or a concentrated solution is solidified or deposits crystals on cooling; and in both cases the nice adjustment of labile molecular equilibrium is accompanied by volume hysteresis, undercooling, etc., in the one case, supersaturation, etc., in the other. Hence I conclude logically, I think, that if under proper thermal conditions pressure alone can solidify a liquid, it can also under proper solutional conditions induce crystallization, or the deposit of solid from solution.

I am the more justified in drawing these references, as in my article[1] on the solvent action of hot water on glass I already adduced the necessary evidence. Since from one point of view the isothermal compressibility increased proportionally to the time during which the solvent action has been going on, and from another, with the amount of silicate dissolved, to more than three times its original value, the inference is pretty closely at hand that what pressure did in this instance was a mere precipitation of a proportionate amount of dissolved silicate. The volume change thence resulting were put into computation

[1] American Journal, vol. 41, p. 110, 1891.

Digitized by Google

as increments of compressibility, for the precipitated silicate is again dissolved when pressure is withdrawn.

Thus the present work bears upon the nature of solution, for I can not believe that what I have ventured to call cohesive affinities[1] can not differ, except in degree, from the affinities which determine valency. At least, proceeding on such an assumption, I am lead naturally to a theory regarding changes of physical state which I will indicate elsewhere.

Finally, in justice to myself let me say that the manuscript left my hands before the kindred deductions of Orme Masson[2] or of Ramsay[3] had reached me. In fact, what these gentlemen have deduced from the solution behavior liquid-liquid I had legitimately derived from the solution behavior solid-liquid, as set forth in my own work. My preceding paper was at fault only in postulating an unnecessary change of hydration of the silicated water (loc cit., p. 116).

It is gratifying to note that evidence of the similar solution behavior solid-solid is forthcoming, and to be found in the work of Osmond, of C. A. Carus-Wilson,[4] and of myself, as I have already pointed out.[5]

CONCLUSION.

96. In the above pages I have merely endeavored to describe the results directly obtained by experiment, and to draw such conclusion, which, in the light of known facts, seemed to be admissible or even obvious. In view of the detailed analogy which holds between many characters of fusion and of solution, I believe that much that can be investigated for the simpler of these phenomena (fusion) will be applicable also to the other. How far the above conclusions as a whole are to stand or fall will depend on similar investigations, which I shall continue to make with a variety of other substances specially selected with reference to their position in a scale of thermal state. How such selection is to be made I am now unable to surmise. Substances, for instance, which fuse continuously, like glass or sealing wax, might at first sight be conjectured to lie near their critical points, but I believe these cases are mere solution phenomena of relatively small interest. At all events the experiments must deal with substances of definite and preferably crystalline character and not with mixtures. I feel confident that in an examination of many types some will be found lying relatively nearer the critical point, while others lie nearer or even beyond the transitional point; and that if the above method be applied with greater rigor than was done in the present paper light will be thrown on the long-neglected department of fusion thermodynamics. From

[1] American Journal, vol. 41, p. 115.
[2] Masson: Nature, vol. 43, 1891, p. 345.
[3] Ramsay: Nature, vol. 43, 1891, p. 589.
[4] C. A. Carus-Wilson: Phil. Mag., vol. 29, p. 200.
[5] Barus: Phil. Mag., vol. 31, 1891, pp. 26–28.

Digitized by Google

this stage of progress it will then be possible to approach nearer the next of the kindred phenomena, which I conceive to be nothing less than the kind of hysteresis or higher order of volume lag commonly known as chemical affinity.

To obviate the occurrence of a bald statement like the last, I will indicate my views on the distribution, or successive orders of volume lags. These are to be sought—I, during the passage of a given atom into the next consecutive in a scale of decreasing atomic weights; II, during the occurrence of dissociation of the molecule, including solutions gas-fluid. They are demonstrable, III, the region of Andrews's vapor tensions, including the Alexéef-Masson solutions liquid-liquid; IV, in the region of the solid-liquid phenomena of the present paper, including solutions solid-liquid; V, in the region of solid-solid phenomena categorically distinguishable as "permanent set" (Osmond, Carus-Wilson, Barus). They are to be sought for finally, VI, during the passage of a given atom into the next consecutive in a scale of increasing atomic weights.

The enumeration is systematic, and inasmuch as VI is virtually identical with I, the inherent nature of these changes is periodic. Hence, under suitable thermal conditions and continually increasing pressure, the evolution of atoms, of molecules, of changes of physical state, are successive stages of periodically recurring hysteresis.

Digitized by Google

Digitized by Google

INDEX.

	Page.
Affinity, chemical, relation to hysteresis	97
Air thermometer comparisons	47, 50
Alcohol, isometrics of	44, 53
Amagat, manomètre of	17, 32, 63
on compressibility of glass and of mercury	78
Andrews's screw compressor	17, 32
Bibliography of isometrics	60
for melting point and pressure	71
Bourdon gauge	23, 25, 26, 63, 64
helical	29, 30
mechanism of	65
theory of	67
Calibration of fusion tube	79
Carus-Wilson, experiments of	96
Compressibility of glass	55
of organic liquids	55, 56
of glass and of mercury	78
nstants of fusion tube	77
ntinuity of solid and liquid	71
rrections for volume changes of glass	
ibes	57, 78
C teria for fusion	71
C tical points	92, 96
C rvature of isometrics	58, 59
ycles in gauge comparisons	25, 27, 64, 66, 67
Data for fusion under pressure	92, 94
Desgoffe, differential manometer of	17
Diphenylamine, isometrics of	45, 54
Dupré on isometrics	60
Electrolytes, temperature and pressure coefficients of	82
Ether, purified	42
isometrics of	38, 41, 42, 51
Expansion (thermal) of glass	54
Fraunhofer micrometer	66
Fusion under pressure, methods of	72, 77
tube for	74
data for	92, 94
Fusion tube, constants for	77
Fusion, types of	94
Galvanometer, torsion	46
Gasket of marine glue	18
Gauge comparisons, cyclic	25, 27, 64, 66, 67
summary	69
Gibbs, notation of	33
Glass, thermal expansion of	54
compressibility of	55
isometrics of	55, 61
dissolved by hot water	95
unow, cathetometer of	80
Hannay and Hogarth, screw compressor of	17
Hysteresis, in gauge comparisons	66
on fusion and solidifying	89
bibliography of	90
recurring orders of	97
Ice type of fusion	94, 95
Iddings on fusion of diabase	81
Isometrics, liquids	33
ether	38, 41, 42, 51
alcohol	44, 53
toluidine	45, 54
diphenylamine	45, 54
thymol	45, 53
corrected	51
curvature of	58
initial slopes of	59
bibliography of	60
glass	55, 61
Isopiestics, relation of, to transitional point	94
Isothermals of solid naphthalene	84
of solid-liquid naphthalene	85, 86, 87, 88, 89
of naphthalene, charts for	89
Kopp's volume flask	73
Lévy on isometrics	60
Manomètre of Amagat	18, 32, 63
Marine glue, gasket of	18
Masson, views of	96
Melting and solidifying points	93
Methods for studying fusion under pressure	72, 77
Mousson, compressor of	32
Naphthalene, isothermals of	84, 85, 86, 87, 88, 89
Notation of Gibbs, Ramsay and Young, etc	33
Periodic relations	95
Piezometer	20, 21, 37, 74
fully adjusted	77
"Piston libre"	70
Pressure, high, measured	17
internal	61
reducer of	70
coefficient of electrolytes	82
effect of, on solution	95, 97
Ramsay and Young on isometrics	60
views of	96
Resistance, how measured	79
electrolytic relation to temperature and pressure	80

Digitized by Google

Page.

Screw compressor of Andrews 17
of Hannay and Hogarth 17
for high pressures 18, 31
Slopes, initial of isometrics 59
Solidifying and melting points 92
Solution under pressure 95, 97
Steel tube cold drawn, weldless 20
Tait describes Amagat's manometre 18
gauge of 22, 23, 25, 26, 32, 63, 67
on elastics of tubes 29
Tinned screw 18
Temperature coefficient of electrolytes .. 82
Thomson, James, double inflections of .. 90
Thymol, isometrics of 45, 53
Toluidine, isometrics of 45, 54
Torsion galvanometer .....
Transitional point related to isopiestics.
Tube of constant volume .....
Tubes, glass, corrections for .....
Tube for fusion under pressure .....
Types of fusion .....
Vapor baths 30, 36, 47,
Volume flask of Kopp .....
Volume of tube in terms of electric resistance .....
Volumes, characteristic specific .....
Volume lag, successive orders of .....
Young. *See* Ramsay.
Zinc sulphate solution, thermal and pressure coefficients of .....

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

3 2044 055 613 616

U.S. Geological Survey
Bulletin 14,87-96

DATE DUE	BORROWER'S NAME

Digitized by Google

Digitized by Google